Remedial Investigation Report

West Lake Landfill
Operable Unit 2
Bridgeton, Missouri

Revised September 2005

HERST & ASSOCIATES, INC.

4630 South Highway 94
North Outer Road
St. Charles, Missouri 63304
Telephone: (636) 939-9111
Facsimile: (636) 939-9757

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1.0 INTRODUCTION

This Remedial Investigation (RI) report has been prepared by Herst & Associates, Inc. on behalf of Allied Waste Industries (Bridgeton), Inc. The RI report has been prepared as part of the Remedial Investigation/Feasibility Study (RI/FS) for Operable Unit 2 (OU-2) at the West Lake Landfill site (the Site) located in Bridgeton, Missouri.

The RI report has been prepared in accordance with the requirements of Administrative Order on Consent (AOC) Docket number VII-94-F-0025, between the U.S. Environmental Protection Agency (EPA) and the Respondent for OU-2 at the West Lake Landfill. Specifically, this report presents the information required by Section 4.2 of the Remedial Investigation/Feasibility Study (RI/FS) Statement of Work (SOW) to the AOC.

1.1 Purpose and Scope of the Remedial Investigation Report

The purpose of the RI report is to present the results of the various site characterization activities. As required by Section 4.2 of the SOW of the AOC, the RI report should summarize the results of the field activities conducted to characterize the following:

- Site physical and biological characteristics
- Sources of contamination
- Site hydrogeologic conditions
- Quality of groundwater, surface water, and sediments; and
- Conceptual site model that identifies contaminant migration pathways and potential receptors.

Each of these requirements is addressed in later sections of this report.

1.2 Site Background

This section presents a brief description of the Site and its location, an overview of past and current landfill operations at the Site, and a discussion of activities occurring adjacent to the Site.

1.2.1 Site Description and Location

The West Lake (Bridgeton) Landfill site is a 212-acre facility located within the City of Bridgeton, St. Louis County, Missouri (Figure 1-1). The site address is 13570 St. Charles Rock Road. The site includes an active solid waste landfill, a closed demolition landfill, an inactive landfill, concrete and asphalt plants, and an automobile repair shop (Figure 1-2). The site was used agriculturally until 1939, when a limestone quarry and crushing operation was initiated.

As shown in Figure 1-2, the West Lake Site is bounded on the north by St. Charles Rock Road and on the east by Taussig Road and agricultural land. Old St. Charles Rock Road borders the southern and western portions of the site. Property north of the site (across St. Charles Rock Road) is moderately developed with commercial retail and industrial operations. The property northeast of the site is also developed for commercial uses. The property south of the site is currently experiencing significant commercial development. The Earth City industrial park is adjacent to the site on the west. The West Lake Site is now almost completely surrounded by commercial/industrial properties.

The southern portion of the Site is zoned M-1 (manufacturing district, limited). A zoning and land use map are shown in Figure 1-2. The southernmost portion of the Site is permitted for active sanitary landfill operations (Permit No. 118912). Although the northern portion of the Site is zoned R-1 (one family dwelling district), a deed restriction has been recorded against the entire Site prohibiting residential use and groundwater use. The deed restriction cannot be terminated without the written approval of the current owners, MDNR, and EPA.

The site is located in the eastern edge of the Missouri River floodplain. The Missouri River is located approximately two miles west of the site. The site remained above the high water elevation during the St. Louis-area floods of 1993 and 1995. The area is transitional between the alluvial floodplain immediately to the west and the loessial bluffs 0.5 miles to the east. The edge of the alluvial valley is oriented north to south through the center of the site (Figure 1-2). Topography in the area is gently rolling. However, site topography has been significantly altered by quarry activities in the eastern portion, and placement of mine spoils (unused quarry rock) and landfilled materials in the western portion.

The limestone quarry was operated between 1939 and 1988, and was closed when economically recoverable reserves were exhausted. The quarry consists of two pits, which were excavated to a maximum depth of about 240 feet below ground surface (bottom elevation of about 240 feet above mean sea level, MSL). The active sanitary landfill is operated within the former limestone quarry. Landfilling operations were initiated within the north pit of the quarry in 1979. Landfilling in the north pit terminated at a maximum elevation of about 500 feet MSL. Currently, the south pit is filled with solid waste to an elevation of about 580 feet MSL.

The landfill has been constructed with a gas collection system and separate leachate collection system. The gas collection system is designed to alleviate potential odor problems and recover gas for potential beneficial use. The leachate collection system is of hydrogeologic importance because it is designed to remove surface water and groundwater which flow into the active sanitary landfill. The leachate collection system, therefore, acts as a groundwater sink to the groundwater surrounding the active landfill. The leachate collection system currently includes six leachate collection sumps (Figure 1-3). Five of the sumps (LCS-1A, LCS-1B, LCS-2B, LCS-3B, and LCS-4A) are located within the former quarry pit, and extend to approximately the base of the landfill (i.e., about 240 feet below pre-existing ground surface). Original leachate risers were labeled LCS-1 through LCS-4, and have been replaced through time with "-A" risers and "-B" risers as the original and replacement risers have in turn been replaced. The sixth leachate collection sump, labeled K-128 (AKA LCS-128K), is found adjacent to the former quarry pit. Sump K-128 is approximately 30 feet deep, and is pumped to remove groundwater within the alluvial materials adjacent to the landfill. These have been fitted with pumps which discharge pumped leachate to an adjacent lined retention and aeration pond (referred to as the Leachate Retention Pond). LCS-1A, LCS-1B, LCS-2B, LCS-3B, and LCS-4A are located near the four corners of the south pit, and extend from the active sanitary landfill surface to the pit floor. In accordance with terms of the landfill permit, the sump pumps are typically activated to maintain a maximum of 30 feet of leachate head in the landfill. The leachate collection system collects an average of about 200,000 gallons of leachate per day from the active landfill area. The collected leachate is pumped to the St. Louis Metropolitan Sewer District (MSD). Through 2004, leachate was pumped to a temporary leachate holding pond, where it was aerated prior to discharge to MSD. In 2004, the leachate holding pond underwent clean closure by draining the pond and removing accumulated sediments. A report was submitted to EPA in April 2005 documenting the leachate pond closure.

1.2.2 Summary of Landfill Operations at the Site

The following historical operations summary was derived from McLaren-Hart (1994) and has been supplemented with other pertinent information.

Mine spoils from the quarrying operations were deposited on adjacent land immediately to the west of the quarry, within the OU-2 study area. Limestone, concrete, and asphalt processing was conducted on-site during quarry operations; asphalt and concrete activities continue to date. The processing operations were conducted primarily in the central portion of the facility. Beginning in the early 1950s, portions of the quarried areas and adjacent areas were used for landfilling municipal refuse, industrial solid wastes and construction demolition debris. It has been alleged, but never substantiated, that liquid wastes were also placed in the landfill. Initial landfilling activities were not subject to State permitting, and the portion of the landfill where these activities occurred has been termed the "unregulated landfill". In 1974, a State landfill permit was obtained and landfilling began in the portion of the Site described as the North Quarry Pit. Landfilling continued in this area until 1985 when the landfill underwent expansion to the southeast in the area described as the South Quarry Pit. Landfill activities conducted after 1974 within the quarry area were subject to a permit from the Missouri Department of Natural Resources (MDNR).

Based on available data, solid waste disposal may have begun at the site as early as 1952 (Midwest, 1994), although many sources cite 1962 as the initiation date for waste disposal. Waste disposal in Missouri was regulated solely by St. Louis County authorities until 1974, when the Missouri Department of Natural Resources (MDNR) was formed. At the West Lake site, the MDNR closed certain waste disposal sites on the northern portion of the site and issued State permits for disposal of sanitary and demolition wastes in other areas. Waste disposal continued during and after cessation of mining activities, using the quarry pits as landfill cells. The MDNR permit areas are highlighted on Figure 1-4. Site ownership is shown on Figure 1-5.

The West Lake site has been divided into two operable units. Operable Unit 1 (OU-1) consists of two areas of radiologically impacted materials present at the West Lake Landfill and a third area of impacted soils at the adjacent off-site property formerly owned by Ford Motor Credit Company and referred to in previous documents as the Ford property. The radiologically impacted materials in OU-1 originated when 8,700 tons of leached barium sulfate residues containing approximately 7 tons of uranium were mixed with approximately 39,000 tons of soil during a cleanup of Cotter Corporation's facilities at 9200 Latty Avenue from July to October, 1973. Cotter Corporation had stored the 8,700 tons of leached barium residues, which it obtained through Continental Mining Corporation from the Department of Energy, at the Latty Avenue facility. B&K Construction transported the materials to the site, where it represented the materials as "clean" fill to site personnel. The materials apparently were used as daily and intermediate cover in routine landfill operations (NUREG-1308, "Radioactive Material in the West Lake Landfill, Summary Report," June 1988). The site was placed on the National Priorities List (NPL) in 1990, based primarily on the presence of radiological isomers and the associated potential for groundwater contamination. Operable Unit 1 is being characterized under *Administrative Order on Consent*, Docket No. VII-93-F-

0005 (EPA, 1993a). A baseline risk assessment has previously been prepared for OU-1 (Auxier, 1998).

Operable Unit 2 (OU-2) refers to areas where landfill activities have been or are being conducted at the West Lake Landfill, with the exception of Operable Unit 1 Area 1 and Operable Unit 1 Area 2. OU-2 was created because of USEPA's inference that the former limestone quarry area had been used for landfilling municipal refuse, industrial solid wastes, and construction demolition debris. USEPA also inferred, based on historic aerial photographs, that standing water pools in what is now the inactive landfill area represented potential liquid disposal areas (Figure 1-6). Potential sludge disposal areas are shown in Figure 1-7.

Characterization of OU-2 is the subject of this Remedial Investigation Report. References to OU-1 conditions, such as hydrogeologic characteristics and nature and extent of OU-1 contamination, have been made in this Remedial Investigation report only when pertinent to OU-2 conditions and to provide site-wide correlation of data.

The landfill can be divided into the following six distinct areas (Figure 1-2):

- Radiological Area 1 within and adjacent to the North Quarry Pit inactive sanitary landfill
- Radiological Area 2 within the closed demolition landfill
- Closed demolition landfill (excluding Area 2)
- Inactive sanitary landfill
- North Quarry Pit inactive sanitary landfill (excluding Area 1), and
- South Quarry Pit landfill (the active sanitary landfill).

These six areas are briefly discussed below. There are also abandoned leachate lagoons and a closed leachate retention pond formerly associated with the sanitary landfill operations (Figure 1-2). A surface water retention pond also was present within the active landfill permitted area, but was removed in 1997.

1.2.2.1 Radiological Area 1

Radiological Area 1 is located immediately to the southeast of the Site entrance. This area was part of the unregulated landfill operations conducted prior to 1974. Based on the drilling logs obtained as part of the RI/FS investigations for OU-1, the waste materials within Area 1 consist of municipal refuse (sanitary wastes) with an average thickness of approximately 36 feet.

Based on the results of the Overland Gamma Survey conducted as part of the RI/FS (McLaren-Hart, 1996b), Area 1 consists of approximately 10 acres that have been impacted by radiological materials. There is an asphalt entrance road and parking area located on the northwestern border of Area 1 near the Site office building. The remaining portions of Area 1 are mainly covered with grass. An underground diesel tank is located beneath the asphalt-paved area in the west portion of Area 1. The tank is no longer in use but has not been removed because it is within the boundaries of Area 1.

1.2.2.2 Radiological Area 2

Radiological Area 2 is located in the northwestern part of the Site. This area was also part of the unregulated landfill operations conducted prior to 1974. Based on the drilling logs obtained as part of the RI/FS investigations for OU-1, the waste materials within Area 2 consist of construction and demolition debris and municipal refuse with an average thickness of approximately 30 feet.

Based on the results of the Overland Gamma Survey conducted as part of the RI/FS (McLaren-Hart, 1996b), Area 2 consists of approximately 30 acres that have been impacted by radiological materials. Large portions of this area are covered with grasses, native bushes and trees while other portions are unvegetated and covered with soil, gravel, concrete rubble and miscellaneous debris consisting of concrete pipe, metal and automobile parts, discarded building materials, and other non-perishable materials. Scattered throughout Area 2 are a number of small depressions, some of which seasonally contain ponded water and phreatophytes such as cattails. The northern and western portions of Area 2 are bounded by the landfill berm, the slopes of which are covered with a dense growth of trees, vines, and bushes.

1.2.2.3 Closed and Inactive Landfill Operations

In addition to Radiological Areas 1 and 2, a closed demolition landfill and an inactive sanitary landfill area are located in the northern and western portions of the Site. The closed demolition landfill is located on the southeast side of Radiological Area 2, between Area 2 and the landfill entrance road. The inactive sanitary landfill is located to the southwest of the closed demolition landfill. Wastes disposed of in these areas are believed to consist of sanitary wastes, a variety of other solid wastes and demolition wastes.

1.2.2.4 Current Active Landfill Operations

The north quarry pit and the south quarry pit are associated with current landfilling operations. Landfilling activities conducted in these areas are subject to a permit issued by MDNR in 1974. Extensive information is available regarding the operations conducted and the nature and configuration of the waste materials disposed of in these areas (McLaren-Hart, 1994). Disposal activities at the north quarry pit were previously completed and this area is currently not receiving waste. As of August 1, 2005, the active landfill ceased receiving municipal solid waste pursuant to an agreement with the City of St. Louis to reduce the potential harm to airport operations from birds that may be attracted to a sanitary landfill. This agreement was recorded as a negative easement on the entire site in April 2005. A transfer station now exists within the area of Operable Unit 2.

1.2.2.5 Activities Adjacent To The Site

The property on the west side of Area 2 (the Ford property) is currently being developed as an industrial park. The subdivision plat for the Ford property, known as Crossroads Industrial Park, currently reflects a 1.785-acre buffer created adjacent to the Area 2 slope. The buffer includes the area of radiological impacted surface soils as identified in the "Phase III Radiological Assessment" performed by Dames and Moore for Ford Financial Services Group (Ford) in 1991. Remedial investigation activities conducted as part of the OU-1 RI/FS included additional sampling of the Ford Property. These additional results are discussed in the OU-1 RI Report (Engineering Management, 2000a). The boundary of the current buffer zone is shown on Figure 1-8 and is owned by OU-1 Respondent Rock Road Industries, Inc., who purchased it from Ford. The OU-1 Respondents are considering using the additional space in the buffer zone to re-grade the landfill berm/slope area along the northern portion of Area 2 as a component of the remedial action that may be selected by EPA for OU-1.

1.2.3 Summary of Previous Investigations

Numerous investigations of the Site have previously been completed and/or summarized. These include pre-RI reports, the OU-1 and OU-2 RI/FS Work Plans and related documents, field and laboratory investigations for the OU-2 RI/FS, OU-1 reports, reports prepared as part of the landfill development and operations at the Site, and investigative reports associated with the Ford property located immediately northwest of OU-1 Area 2. These investigations are described below.

The following OU-2 RI/FS Work Plans and Investigative Reports were previously prepared:

- Final Remedial Investigation/Feasibility Study Work Plan for the West Lake Landfill Operable Unit 2, Bridgeton, Missouri, April 1995 (Golder Associates)
- Draft Hydrogeological Characterization Report for the Bridgeton Active Sanitary Landfill, Bridgeton, Missouri, September 1995 (Golder Associates)
- Physical Characterization Technical Memorandum for the West Lake Landfill Operable Unit 2, Bridgeton, Missouri, November 1996 (Golder Associates)
- West Lake Landfill, Operable Unit 2 RI/FS, Site Characterization Summary Report, December 1997 (Water Management Consultants)
- West Lake Landfill, Operable Unit 2 Baseline Risk Assessment Report, February 2000 (GlobalTox, Inc.)

1.3 Report Organization

The remainder of this report is organized as follows:

- Section 2 presents a summary of previous investigations;
- Section 3 describes physical characterization activities at the Site;
- Section 4 describes the chemical characterization and nature, occurrence and distribution of the sources of contamination at the Site including affected media, location, types of contamination, physical state of contaminants, contaminant concentrations and quantity of contaminant and affected media;
- Section 5 present the Quality Assurance and Data Validation for lab results;
- Section 6 presents the Baseline Risk Assessment;
- Section 7 presents treatability testing;
- Section 8 presents a summary of the Site conditions; and
- Section 9 presents the references used for this report.

2.0 STUDY AREA INVESTIGATION

Numerous investigations pertaining to hydrogeological and environmental conditions have been conducted at and around the West Lake Site. These investigations focused primarily on environmental conditions originating from inactive portions of the site. However, these investigations include information pertinent to hydrogeologic characterization of the entire site. A chronological listing and brief summary of the previous investigations performed at the site is provided in Table 2-1.

Prior to the West Lake Landfill OU-2 RI, the most extensive previous hydrogeological investigation conducted at the Site was performed by Burns & McDonnell (BMD) of Kansas City, Missouri, in 1986. This investigation was oriented towards the inactive landfill area located on the western portion of the Site. Boreholes were drilled and monitoring wells were installed at shallow, intermediate, and deep depths of the alluvial aquifer. The *Hydrogeologic Investigation, West Lake Landfill, Primary Phase Report* (BMD, 1986) included the following conclusions:

- The alluvium of the Missouri River forms the major aquifer in the vicinity of the site. The underlying bedrock is relatively impermeable, both on the valley side slopes and the bedrock valley buried beneath the alluvium.
- Alluvial deposits of the Missouri River are in hydraulic communication with the river; thus the river has a major influence on water levels in the alluvium. A rise in river stage during seasons of high rainfall and snow melt causes the water table in the aquifer to rise. Conversely, a seasonal drop in the river stage causes the water table in the aquifer to drop. Although the rise and fall of the aquifer is less than that of the correlative change in river stage, the change in water table elevation is relatively uniform throughout the entire extent of the site vicinity.
- The predominant direction of groundwater flow in the alluvial aquifer in the region near the site is northwestward toward the Missouri River. There are broad fluctuations in this flow direction throughout the year and the predominant flow direction ranges slightly south of due west to northwest.
- Throughout most of its extent, the alluvial aquifer is generally unconfined (under water table conditions). Relatively low-permeability, discontinuous clayey and silty zones in the upper part of the alluvium may cause semi-confined and perched water conditions in very localized areas.

Subsequent sections of this RI Report present the results of the OU-2 field investigation.

2.1 Meteorological Investigations

The climate of the Site is typical of the Midwestern United States with a modified continental climate that has four distinct seasons.

2.1.1 Temperature

Winter temperatures are generally not severe with the first frost usually occurring in October and freezing temperatures generally not persisting past March. Records since 1870 show that temperatures drop to zero (0°F) or below an average of two to three days per year. Temperatures remain at or below freezing (32°F) less than 25 days in most years.

Summers in the St. Louis area are hot and humid. The long-term record since 1870 indicates that temperatures of 90 degrees Fahrenheit or higher occur on about 35 to 40 days per year. Extremely hot days of 100 degrees Fahrenheit or more generally occur no more than five days per year.

2.1.2 Precipitation

Precipitation data from the period of 1961 through May 2005 as measured at nearby Lambert St. Louis International Airport is presented in Table 2-2. Lambert St. Louis International Airport is located approximately 3.7 miles east of the Site. The average annual precipitation for the area over the period of record is about 38 inches.

The three winter months are usually the driest, with an average total of approximately 6 inches of precipitation. Average snowfall per winter season is slightly greater than 18 inches. Snowfall of an inch or more is received on five to ten days in most years. Record snowfall accumulation over the past 30 years was 66.0 inches recorded during the 1977 – 78 winter season.

The spring months of March through May are the wettest with normal total precipitation of just under 10.5 inches. Thunderstorms normally occur 40 to 50 days per year. During any given year, a few of these storms can be classified as severe with hail and damaging wind. Tornadoes have occurred in the St. Louis area.

2.1.3 Wind Distribution

Between December and April, the predominant wind direction at Lambert Field is from the northwest and west-northwest. Throughout the remainder of the year, the predominant wind direction is from the south. Considering potential differences in topography between Lambert Field and the Site, the actual wind directions at the Site may be slightly different, possibly skewed in a northeast-southwest direction parallel to the Missouri River Valley.

2.2 Surface Features

This section includes a description of the Site topographic conditions, surface soil conditions, runoff drainage patterns, and surface water bodies in the area.

2.2.1 Topography

The Site is situated within the western portion of the St. Louis metropolitan area in northeastern St. Louis County. Located at the confluence of the Missouri and Mississippi Rivers (Figure 1-1), the St. Louis metropolitan area consists of Jefferson, St. Charles, and St. Louis counties in Missouri, as well as adjacent counties in Illinois. The northeastern two thirds of St. Charles and St. Louis counties, and the extreme northeastern part of Jefferson County, lie within the Dissected Till Plains of the Central Lowland physiographic province (Miller et al., 1974).

The gently undulating Dissected Till Plains range in elevation from about 450 to 700 feet MSL. The area was glaciated twice during the Pleistocene era, but the morainal topography typical of adjacent glaciated areas is not present. The till deposits are thin and dissected due to post-Pleistocene erosion.

2.2.2 Surface Soils

According to the US Soil Conservation Service (SCS), surficial materials along the floodplain of the Missouri River generally consist of the Blake-Eudora-Waldron association, while the surficial materials on bluffs east of the river are the Urban Land-Harvester-Fishpot association (SCS, 1982). The floodplain materials are described as nearly level, somewhat poorly drained to well drained, deep soils formed in alluvial sediment. The upland materials are urban land and nearly level to moderately steep, moderately well drained to somewhat poorly drained, deep soils formed in silty fill material, loess, and alluvium, which were formed on uplands, terraces, and bottom lands.

Soils in the immediate vicinity of the site consist of the Freeburg-Aston-Weller association, which are nearly level to gently sloping, somewhat poorly drained to well drained, deep soils formed in loess and alluvial sediment. The Freeburg silt loam is found on the terrace adjacent to the eastern site boundary, while the Ashton silt loam is found to the east and south of the south pit (including the current active landfill borrow area).

The Freeburg unit is identified as a somewhat poorly drained silt loam to silty clay loam, up to 60 inches thick. Permeability of this soil is characterized by the SCS as moderately slow (about 10^4 centimeters per second, cm/sec), and the surface runoff is medium. According to the SCS, a perched water table is often present within this unit in the spring, at a depth of 1.5 to 3 feet. The Freeburg unit's suitability for landfill daily cover is described as fair, due to the clay content (12 to 35 percent) and wetness.

The Ashton unit is a well drained silty loam to silty clay loam, also up to 60 inches thick. Permeability of this unit is also moderately slow, and the surface runoff is medium. The suitability of the Ashton unit for landfill daily cover is described as fair, due to the clay content (10 to 40 percent).

2.2.3 Surface Water

Three major rivers, the Mississippi, the Missouri, and the Meramec, pass through the region and supply nearly all the water used in the St. Louis area (Emmett and Jeffrey, 1968). The Mississippi River flows to the south along the eastern Missouri state border. The Missouri River generally flows to the east across Missouri through the western and northern portions of the metropolitan area and discharges into the Mississippi River north of St. Louis. The Meramec River flows along the southern portion of the metropolitan area and discharges into the Mississippi River south of St. Louis. Other minor rivers and streams in the area are tributaries to these three rivers. A few other minor surface water features (such as lakes) are present in the St. Louis metropolitan area.

The present channel of the Missouri River lies about two miles west and northwest of the site. Historic land surveys indicated that approximately 200 years ago the channel was several hundred yards east of its present course (Banerji et al., 1984). The Missouri River has a surface slope of 0.00018 feet per foot. The reference river stage at St. Charles (upstream and west of the site), Mile 28, is 413.7 feet MSL. Average discharge for the Missouri River is 77,300 cubic feet per second (cfs), with a typical minimum flow of about 40,300 cfs in December and January and a typical maximum flow of about 100,750 cfs in April through July.

Precipitation that falls into the Missouri River floodplain generally infiltrates the alluvial deposits. The floodplain is relatively flat, and the sediments have an infiltration index of 3.5 inches (Miller et al., 1974). Streams present within the floodplain originate in the surrounding uplands.

Drainage patterns within the floodplain west of the site have been altered by flood control measures taken to protect nearby commercial development, and by the drainage of local swamps and marshes. Before these alterations, Creve Coeur Creek flowed just south of the site along Old St. Charles Rock Road. A stormwater retention pond encompassing a portion of the old Creve Coeur Creek channel is present west of the site, adjacent to the Earth City industrial park.

Surface drainage at the site is indicated in Figure 2-1. In general, surface water from the eastern portion of the site flows towards the site surface water retention pond. Based on a 36-acre landfill footprint, 37-inches of precipitation per year, conservatively assuming no evaporation, and recognizing that no runoff can occur from the below-grade active landfill, precipitation falling into the sanitary landfill is estimated to contribute an average of 99,000 gallons per day to the approximately 200,000 gallons per day of leachate pumped. Precipitation falling in the active sanitary landfill is recovered by the leachate collection system and discharged to the leachate retention pond. Surface runoff in the western portion of the site generally flows toward Earth City industrial park stormwater retention pond, or westward in a drainage ditch along St. Charles Rock Road. Stormwater dikes are present around the landfill to prevent run-on from neighboring properties.

2.3 Geological Investigation

The subsurface conditions beneath the landfill consist of municipal refuse, construction and demolition debris, other wastes and the associated cover materials, alluvial deposits and limestone, dolomite and shale bedrock.

The bedrock geology of the Site area consists of Paleozoic age sedimentary rocks that in turn overlie Pre-Cambrian age igneous and metamorphic rocks. The Paleozoic bedrock is overlain by unconsolidated alluvial and loess deposits of recent (Holocene) age. A generalized stratigraphic column for the St. Louis area is presented on Table 2-4. Bedrock contour map is shown in Figure 2-2.

The lowermost bedrock unit beneath the Site consists of Pre-Cambrian igneous and metamorphic rocks that are overlain by cherty dolomite, siltstone, sandstone and shale of Cambrian age. These deposits are overlain by approximately 2,300 feet of limestone, dolomite, shale and sandstone of Ordovician age which in turn are overlain by approximately 200 feet of cherty limestones of Silurian age. Devonian age sandstone, limestone and shale deposits lie unconformably on the Silurian age deposits.

The uppermost bedrock units in the vicinity of the Site consist of Mississippian age limestone and dolomite with inter-bedded shale and siltstone layers of the Kinderhookian, Osagean, and Meramecian Series. The Kinderhookian Series is an undifferentiated limestone, dolomitic limestone, shale and siltstone unit ranging in thickness from 0 to 122 feet in the St. Louis area. The Osagean Series consists of the Fern Glen Formation, a red limestone and shale, and the Burlington-Keokuk Formation, a cherty limestone. The Fern Glen Formation ranges in thickness from 0 to 105 feet and the Burlington-Keokuk Formation ranges from 0 to 240 feet thick in the St. Louis Area.

The Meramecian Series overlies the Osagean Series rocks. The Meramecian Series consists of several formations including the Warsaw Formation, the Salem Formation, the St. Louis Formation, and the St. Genevieve Formation. The St. Genevieve Formation is reportedly not present in the vicinity of the Site (Golder, 1996).

Pennsylvanian-age Missouri, Desmoisian, and Atokan formations are present in some areas above the Mississippian-age rocks. The Pennsylvanian-age rocks consist primarily of shale, siltstone, and sandstone with silt and clay. These formations range in combined thickness from 0 to 375 feet in this area. The Atokan-Series Cheltenham Formation was identified as being present in the landfill soil borrow area located in the southeastern corner of the Site.

Bedrock formations of hydrologic importance underlying the West Lake site are sedimentary members of the Paleozoic Mississippian and Pennsylvanian systems. The Mississippian System formations present include the Osagean and Meramecian Series (Thompson, 1986). The bedrock formations on interest beneath the site, listed in order of oldest to youngest, consists of the Keokuk (upper portion of the Osagean Series), the Warsaw Formation (lower portion of the Meramecian Series), the Salem Formation (middle portion of the Meramecian Series), the St. Louis Formation (middle portion of the Meramecian Series) and the Cheltenham Formation (lower portion of the Pennsylvanian System). The upper portion of the Meramecian Series (St. Genevieve Formation) is not present at the site.

2.4 Hydrogeology

Hydrogeologic characterization of a site requires an understanding of the hydrogeologic system controlling groundwater flow.

The scope of the hydrogeologic study portion of the physical characterization focused on both the saturated and unsaturated units of the St. Louis and Salem Formations, the Warsaw Formation, and the upper unit of the Keokuk Formation, and their interaction with local hydrogeologic controls. Pertinent hydrogeologic controls include formational boundaries, the quarry, and other potential recharge and discharge sources (seeps, leachate collection system, precipitation, and the Missouri River).

2.4.1 Regional aquifers

Groundwater is present in the region in both unconsolidated materials (alluvium) and bedrock, as described below.

The major alluvial aquifers in the area are differentiated to include the Quarternary age alluvium and the basal parts of the alluvium underlying the Missouri River floodplain. The floodplain alluvial aquifers are typically exposed at the surface and can be as much as 150 feet thick (Miller, et al., 1974).

Bedrock aquifers in the St. Louis area which are favorable for groundwater development include the Ordovician-age St. Peters Sandstone, Roubidoux Formation, and Gasconade Dolomite, as well as Cambrian-age Potosi Dolomite. Miller (et al., 1974) describes the uppermost regional aquifers (Pennsylvanian, Mississippian, Devonian, and Silurian) as yielding small to moderate quantities of water, ranging from 0 to 50 gpm. The Ordovician-age Maquoketa shale of the Cincinnatian-series underlying these systems probably constitutes a confining influence on water movement from underlying aquifers favorable for groundwater development. Deeper Ordovician-age and Cambrian-age aquifers described below are considered favorable as non-potable water sources.

The St. Peter Sandstone aquifer lies at a depth of approximately 1,450 feet below ground surface and can be as much as 160 feet thick. The average depth of the Roubidoux Formation is approximately 1,930 feet. Thickness of this unit in the St. Louis area ranges from 0 to 177 feet. The Gasconade Dolomite directly underlies the Roubidoux Formation. The Gasconade and associated Gunter Sandstone occur in thickness of up to 280 feet. The Potosi Dolomite can be present in thicknesses of up to 324 feet, at an average depth of 2,240 feet. It should be noted that the thickness and depth of these formations varies throughout the St. Louis area, and they may not be present in some places.

While of regional importance, none of the above aquifers are relevant to the West Lake Landfill site due to their great depths and overlying Maquoketa shale confining unit.

The Mississippian-age Meramecian Series immediately underlying and adjacent to the West Lake Landfill site (including Warsaw, Salem, and St. Louis Formation) are not identified as favorable for groundwater development (i.e., yield less than 50 gallons per minute (gpm) to wells) (Miller et al., 1974).

2.4.2 Regional Wells

Alluvial groundwater wells completed in the Mississippi and Missouri River floodplains are capable of yielding more than 2,000 gpm (Emmett and Jeffrey, 1968). However, no public water supply wells within the vicinity of the site draw from the alluvial aquifer (Foth & Van Dyke, 1989). Wells yielding up to about 50 gpm can be developed in bedrock aquifers overlying the Maquoketa shale described above (Miller, et al., 1974).

As part of the OU-2 RI, the State of Missouri was contacted, and it provided a listing of registered wells in the area of the West Lake Landfill, more specifically in T46N, R5E and T47N, R5E. These Township / Range coordinates encompass approximately 5 miles surrounding the West Lake Landfill. The State of Missouri information is provided in Appendix A. The locations of the registered wells are illustrated on Figure 2-3. There are no registered wells between the West Lake Landfill and the Missouri River in the direction of regional groundwater flow.

The closest registered well is approximately one mile northeast of the landfill. This particular well is reportedly drilled 245 feet deep. Based on the geology of the area, the depth indicates a bedrock completion. Regional groundwater flow is toward the northwest and the Missouri River. Accordingly, the nearest registered well is not downgradient of the landfill. The closest registered well that appears to be completed in alluvium is approximately 2.5 miles south of the landfill. Areas south of the landfill are upgradient to the landfill.

A review of unregistered wells was also conducted. The State of Missouri maintains a listing of private wells that were installed prior to the adoption of formal well registration requirements. The listing is provided in the Missouri Environmental Geology Atlas (MEGA). The State of Missouri notes that the MEGA database may not accurately reflect current conditions. The MEGA database identified fifteen private wells in the vicinity of the West Lake Landfill, which were drilled between 1924 and 1972. Appendix A presents the MEGA data.

As a further check on the reliability and thoroughness of the field reconnaissance, addresses listed in the MEGA database were compared to the listed UTM coordinates, in those instances where the database included both sets of location information, to confirm that the appropriate locations were included in the evaluation. Three of the fifteen unregistered wells had both an address and a UTM location listed in the MEGA database. There were slight inconsistencies between the UTM location and the address. A field reconnaissance described more completely below included both the UTM location and the address, to provide additional assurances that the field reconnaissance was complete.

The field reconnaissance of the unregistered wells was performed in August 2005. Several industrial facilities/warehouses have been constructed where residences may have previously existed. Additionally, recent expansion of the Lambert-St. Louis International Airport has significantly encroached on the area north of the West Lake Landfill, resulting in the demolition of homes and businesses. Following are observations made based on the field reconnaissance:

- 002118 – This well was listed as a noncommunity public well that was drilled in 1926 and was owned by West Lake Park and Amusement #2 located at St. Charles Road and Natural Bridge Road. Herst & Associates, Inc. personnel did not verify the continued existence of this well. This area is significantly developed, and there is no amusement park at or near this location. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 003039 – This well was listed as a private well that was drilled in 1924 and was owned by West Lake Park #1 located at St. Charles Road and Natural Bridge Road. Thre is no West Lake Park #1 located at St. Charles and Natural Bridge Road. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 004478 – This well was listed as a private well that was drilled in 1937 and was owned by Mrs. Taylor at a location 2 miles northwest of Pattonville between Gist Road and the Wabash Railroad Tracks. It is believed that the well is located in the airport expansion area. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 006642 – This well was listed as a private well that was drilled in 1940 and was owned by Carl R. McGee located at 3408 Lucas and Hunt Road, 0.5 miles southwest of St. Charles Rock Road. Herst & Associates, Inc. personnel could not locate this well. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 006794 – This well was listed as a private well that was drilled in 1940 and was owned by Mrs. Frank Lueck, at a location approximately 1/2-mile northeast of the West Lake Landfill. Herst & Associates, Inc. personnel asked the current property owner if a private well existed on the property located at 3840 and 3844 Taussig Road (about 0.25 miles north of St. Charles Rock Road). The property owner indicated that a private well does exist at his property but the well is no longer used. The property owner indicated that the residence and area were serviced by a city water supply.
- 007206 – This well was listed as a private well that was drilled in 1941 and was owned by Cabibbo. Herst & Associates, Inc. personnel did not verify the continued existence of this well. Remarks in the MEGA database indicate that the well was located 1 mile west of Lindburgh on the south side of Natural Bridge Road. It is believed that the well is located in the airport expansion area and therefore would no longer exist.

- 010022 – This well was listed as an Industrial High Capacity Well that was drilled in 1948 and was owned by West Lake Quarry and Material Company. This property is now occupied by the Redbird Concrete Company. Redbird personnel were interviewed as part of the field reconnaissance activities and state that the site has been supplied by city water since the mid-1980's. Redbird personnel do not believe that the well still exists.
- 011506 – This well was listed as a private well that was drilled in 1951 and was owned by W.G. Holtsneider. Herst & Associates, Inc. could not locate this well. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 015897 – This well was listed as a private well that was drilled in 1957 and was owned by Jesse Hammel. Herst & Associates, Inc. could not locate this well. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 019849 – This well was listed as a private well that was drilled in 1961 and was owned by Mr. Sam Wilson located at 4740 Garrett Road, Hazelwood, Missouri. There is no house located at 4740 Garret Road. The former residence is believed to have been abandoned due to the St. Louis Airport Expansion. There is a locked gate located at the intersection of Gist and Garrett restricting access to Garrett Road.
- 020676 – This well was listed as a private well that was drilled in 1962 and was owned by Mr. Ike Revelle located at 13039 Gist Road, Bridgeton, Missouri. There is no longer a residence located at 13039 Gist Road. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 021799 – This well was listed as a private well that was owned by John Maloney (drilling date not listed). The property is current occupied by industry. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 024505 – This well was listed as a water test hole that was drilled in 1966 and was owned by the United States Geological Survey (USGS). Herst & Associates, Inc. could not locate this well. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 024553 – This well was listed as a water test hole that was drilled in 1966 and was owned by the USGS. Herst & Associates, Inc. could not locate this well. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.
- 027190 – This well was listed as an unclassified well drilled in 1972 and owned by Linclay – Earthcity. Herst & Associates, Inc. could not locate this well. Based on the field reconnaissance, it does not appear that the unregistered well continues to exist at this location.

Based on the field reconnaissance, only one of the fifteen unregistered wells was verified as present, and the resident at this location stated the well is no longer used because the property is serviced by municipal water.

2.5 Human Population Surveys

The population of the City of Bridgeton, according to the 1990 Census, is 17,779 (US Dept of Commerce, 1994). St. Charles, located across the Missouri River (Figure 1-1) and 1.9 miles from the landfill, has a population of 54,555, and has exhibited a growth of approximately 45 percent from 1980. The City and County of St. Louis decreased in population by nearly 9 percent from 1980 to 1990.

Two small residential communities are present near the West Lake Landfill. Spanish Lake Village consists of about 90 homes and is located 0.9 miles south of the landfill. A small trailer court lies across St. Charles Rock Road, 0.9 miles northeast of the site. Subdivisions are presently being developed 1.2 to 1.9 miles east and southeast of the landfill in the hills above the floodplain.

2.6 Threatened or Endangered Species Assessment

An assessment of the plant communities present at the Site, the potential for the presence of threatened or endangered species and a description of the types of wildlife observed to be present at the Site was performed by McLaren-Hart (1996a) as part of the Operational Unit-1 RI/FS investigations. The results of this survey are presented in the McLaren-Hart report and are briefly summarized below.

The entire area surrounding the West Lake Landfill is rapidly being developed for commercial/light industrial purpose. The area north of the landfill across St. Charles Rock Road, as well as the area west of the landfill in Earth City, has previously been developed. Subsequent to initiation of the OU-2 RI/FS, the areas south and east of the landfill have also undergone extensive commercial/light industrial development. The heavy development in the area has eliminated almost all previously existing plant and animal habitats, and has therefore significantly reduced the number and type of potential ecological receptors.

2.6.1 Plant Communities

According to the Nuclear Regulatory Commission, (1988), the flora along the bottom and lower slope of the berm along St. Charles Rock Road (Figure 1-2) includes silver maple (Acer saccharinum), boxelder (Acer negundo), oak (Quercus spp.), sycamore (Platanus spp.), green ash (Fraxinus pennsylvanica) and eastern cottonwood (Populus deltoides) trees. At the north corner of the Site, large silver maple and boxelder trees form a dense stand in the moist soils at the base of the berm. The density of these trees declines on this slope extending towards the north. The extension of this slope towards the northwest is dominated by a dense willow-like thicket in which eastern cottonwoods and a hawthorn tree have been established. From the northwest corner of the landfill to the east, along St. Charles Rock Road, the exterior slope of the berm has been dominated by dense stands of small and large eastern cottonwoods. The ground cover along these exterior slopes consists of grasses, forbs, plants common to disturbed area, seedling cottonwoods, and shrubs.

The somewhat drier top and the short interior slope of the perimeter berm include prairie grasses such as bluestem (Andropogon spp.). Depressions in the irregular surface of the inactive unregulated landfill allow water to collect and tall grasses, foxtail, and plants characteristic of disturbed areas [e.g., ragweed (Ambrosia spp.), mullein (Verbascum spp.), pokeweed (Phytolacca spp.), cinquefoil (Potentilla spp.), sunflower (Helianthus spp.), and plantain (Plantago spp.)] are replaced by characteristic wetland species [e.g., algae (Spirogyra spp.), cattails (Typha spp.), sedges (Carex spp.), and smartweed (Polygonium spp.)]. Young eastern cottonwoods are established at several of these depressions.
The ground is largely barren near the demolition landfill and the areas associated with recent sanitary landfilling activities.

2.6.2 Threatened and Endangered Species

Federal and State listings of threatened and endangered species were requested from the U.S. Fish & Wildlife Service (USFWS) and from the Missouri Department of Conservation (MDOC) by McLaren-Hart as part of their activities related to preparation of the Operable Unit-1 RI/FS Work Plan (McLaren-Hart, 1994). The USFWS responded that "No federally-listed endangered or threatened species occur in the project area" (USFWS, 1994). The MDOC responded that "Department staff examined map and computer files for federal and state threatened and endangered species and determined that no sensitive species or communities are known to occur on the immediate Site or surrounding area" (MDOC, 1994).

Subsequent to these letters, Ms. Cherri Baysinger-Daniels of the Missouri Department of Health (MDH) stated that on October 23, 1994 she observed a Western Fox Snake (Elaphe vulpine), a Missouri state-listed endangered species, at the Site. The western fox snake is a marsh-dwelling member of the rat snake group (MDOC, 1992). This snake is believed to be an inhabitant of open grasslands and the borders of woods. In Missouri, the fox snake been found near large natural marshes. The western fox snake has currently been documented to be present only in St. Charles and Lincoln counties (MDOC, 1994 and 1995).

In response to Ms. Baysinger-Daniels' observation, McLaren-Hart requested another database search of the western fox snake's distribution in Missouri (McLaren-Hart, 1996a). This second search indicated that there were no records of occurrences of the western fox snake reported for St. Louis County, Missouri. If Ms. Baysinger-Daniels' preliminary observation had been verified, the presence of the western fox snake at the Site would represent a new location for this species and a new county record. A voucher specimen is required to adequately document a new county record (MDOC, 1995). A photograph of a specimen, showing both the dorsal and ventral views, would suffice as a voucher specimen. As a voucher specimen was not obtained, Ms. Baysinger-Daniels's observation alone is insufficient to verify an occurrence of the western fox snake in St. Louis County.

During the field survey, McLaren-Hart examined areas most likely to be inhabited by the western fox snake in an effort to verify and document Ms. Baysinger-Daniels' observation. Each vegetative community, with emphasis on marshy areas, was qualitatively examined for the presence of the western fox snake or other reptiles. The reptile search was performed concurrently with the evaluation of the vegetative communities. Basking areas, large rocks, logs and pieces of plywood were examined for the presence of snakes. No specimens of the western fox snake were observed during the biological survey.

2.6.3 Site Wildlife

The NRC (1988) encountered cottontail rabbits (Sylvilagus spp.) at the site. Coyote (Canis latrans) feces containing rabbit fur were also observed. Small mammals (rodents) were not seen but may be present in this area. No large ungulates were sighted, but tracks and feces of white-tailed deer have been observed.

Few birds were observed early in the spring: a crow (Corvus), several robins (Turdus spp.), and white crowned sparrows (Zonotrichia leucophrys). This does not reflect the extent to which birds utilize the habitat throughout the year. Some migratory passerines may use the surface vegetation and berm thickets for nesting, cover, and feed later in the season. Waterfowl may use the permanent ponds on the landfill and adjacent to St. Charles Rock

Road. Scaup (Aythya spp.) and mallards (Anas spp.) were observed on the leachate retention pond.

Small puddles contained characteristic common aquatic invertebrate and at least two species of amphibians. Snails, and isopod (Asnellus), cyclopoid copepods, and cladocerans were observed in these small puddles. Aquatic insect larvae were not observed. A bullfrog tadpole (Rana catesbeiana) and audition of spring peepers (Hyla spp.) were observed. No fish were observed in puddles on the site, although fishing tackle was found tangled in power lines and trees, indicating that fish may be present. The only reptiles observed were the water snake (Nerodia spp.) and garter snake (Thamnophis spp.).

According to McLaren-Hart (1994), the Missouri Department of Conservation (MDOC) reports 25 amphibian, 47 reptilian, 29 mammalian, and 299 avian species in the regional area of St. Charles County. Many of the terrestrial vertebrates found within this area are widely distributed species. The MDOC has recorded more than 105 species of fish in the regional area, although none appear to exist near the site.

The streamlined risk assessment for OU-2 has identified groundwater as the primary media of concern. Groundwater is not readily accessible to ecological receptors and the site characterization suggests that groundwater will not adversely impact ecologically sensitive areas. Surface water and sediment sampling results do not indicate off-site release of contaminants from run off and on-site sampling do not suggest that there would be releases through run off in the future.

3.0 SITE INVESTIGATION ACTIVITIES FOR PHYSICAL CHARACTERIZATION

The field activities associated with the OU-2 RI/FS were conducted to satisfy the physical characterization requirements of the Administrative Order on Consent for OU-2 (EPA, 1994). The activities were conducted in accordance with EPA-approved OU-2 Work Plan, as detailed in the OU-2 Sampling and Analysis Plan. The activities were performed from January 1995 through June 1996 and were presented to the EPA in a document titled Physical Characterization Memorandum, Golder, 1996. The following sections describe location rationale, sampling rationale, and investigation methodology. Monitoring point locations and elevations were surveyed by Sherbut-Carson and Associates, P.C. of Collinsville, Illinois. Northing and easting coordinates were determined to the nearest 0.1-foot, and related to the North American Datum (NAD) 1983. Top of PVC riser and ground surface elevations were determined to the nearest 0.01 foot. The ground surface elevations were rounded to 0.1 foot. Elevations were related to mean sea level (MSL). All survey data were also related to the site coordinate system. Survey elevation data are included in borehole logs, rock core logs, piezometer construction summaries, and Table 3-1.

Following is a summary of the Physical Characterization techniques and results.

3.1 Meteorology

A precipitation gauge capable of measuring precipitation events greater that 0.01 inch was installed at the site. Precipitation data were combined with regional data from the nearby Lambert Airport, and were used to correlate fluctuations in groundwater levels with precipitation events. Precipitation data from the site and airport monitoring stations are provided in Appendix H-2 of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*. Daily stream flow data from the Missouri River at St. Charles were obtained from the US Geological Survey and are correlated with observed fluctuations in selected piezometers.

Approximate daily readings were recorded on site from June 1 to November 14, 1995, concurrent with the installation of piezometers during the physical characterization. The site and airport monthly precipitation totals are summarized below.

	Total Precipitation (inches)	
	Site Gauge	Lambert Airport
June 1995	2.41	2.96
July 1995	1.77	2.16
August 1995	5.06	4.52
September 1995	0.26	0.74
October 1995	2.51	2.01
November 1-14, 1995	0.87	1.28
Total	**12.88**	**13.67**

As indicated above, precipitation total between Lambert Airport data and site gauge data correlate very well. Based on the good correlation, daily Lambert precipitation data were used after November 14, 1995.

3.2 Surface Water

As described in the *Work Plan*, two surface water and sediment sampling locations were included in the OU-2 RI. The first location was upstream of the site, at a background location south of the site. The second location was within the Earth City Stormwater Retention Pond, at a location that would be expected to receive runoff impacts from the inactive landfill, if impacts occurred. The upstream surface water location was designated SW-01, and the upstream sediment location was designated SED-01. The downstream surface water and sediment sampling locations were designated SW-02 and SED-02, respectively. The downstream surface water and sediment sampling locations were selected to provide data near and potentially downgradient of the monitoring well MW-F2, area which had exhibited potential petroleum impacts through landfill gas monitoring and soil TOC results. Figure 3-1 illustrates the surface water and sediment sampling locations.

Staff gauges, five feet tall, were installed near each surface water/sediment sampling location to measure changes in elevation. The five-foot staff gauges, which are graduated in 0.1 foot increments, were bolted to steel posts. The five foot mark on each gauge was surveyed.

3.3 Geologic Investigation

The OU-2 RI included installation of 49 piezometers to characterize the site hydrogeology and to monitor groundwater elevations in alluvial and bedrock aquifers. Single, paired, and clustered piezometers were installed to evaluate groundwater flow directions and hydraulic relationships in stratigraphic units at the site, as well as to determine subsurface physical characteristics. These forty-nine piezometers were drilled at 33 locations, on average about 350 feet apart. These supplemented existing piezometers and monitoring wells across the site. From the newly-installed piezometers and previously existing piezometers/wells, 24 locations were proposed for inclusion in the groundwater quality monitoring network for OU-2. Figure 3-1 illustrates the OU-2 monitoring locations, plus OU-1 monitoring wells and piezometers. The wells and piezometers sampled in the OU-1 RI are discussed in OU-1 deliverables.

Piezometers were installed in each of the 49 boreholes, under supervision of qualified personnel who were state-certified monitoring well installation contractors.

3.3.1 Piezometer Naming Convention

The piezometers were designated "100-", "200-", and "300-" series, and characterize unconsolidated (loess and alluvium) and bedrock (Salem, St. Louis, Warsaw, and Keokuk Formations) materials. The "100-" series piezometers are generally placed immediately adjacent to the perimeter of the active sanitary landfill, while the "200-" series piezometers are generally located within 500 feet of the active sanitary landfill. The "300-" series piezometers were placed adjacent to the inactive landfill areas in the western portion of the site, and upgradient of the site. Piezometer locations are shown on Figure 3-1.

For alluvial piezometer pairs and clusters installed in the western portion of the site (where saturated alluvium is present), the piezometers were screened:

- At the water table;
- At intermediate depths within the alluvium; and,

- Immediately above the uppermost bedrock.

Bedrock piezometers were screened:

- Approximately 50 feet into the St. Louis and upper Salem Formations for bedrock piezometers in the alluvial valley, or 10 feet below the water table for bedrock piezometers outside the alluvial valley;
- At the bottom of the Salem Formation; and,
- At the top of the Keokuk Formation.

The deepest borings were drilled into the Keokuk Formation and were completed over 150 feet below the inferred base of solid waste in the active sanitary landfill.

Table 3-2 identifies the rationale utilized for siting each of the piezometers, leachate risers, and soil borings. Table 3-1 summarizes piezometer locations, depths, and screened intervals of subsurface sample points.

Piezometers were identified with the prefix "PZ" and a suffix designation specific to the formation being monitored. An "A" suffix was used if the piezometer was completed in alluvium (unconsolidated materials). An "S" suffix was used if the piezometer was completed in the Salem or St. Louis Formation. The "K" suffix was used if the piezometer was completed into the Keokuk Formation. The piezometer identifiers were further modified with an additional suffix designating whether the piezometer was completed into the shallow ("S" suffix), intermediate ("I" suffix) or deep ("D" suffix) portion of the aquifer. Because groundwater in the Keokuk Formation is hydraulically isolated from the overlying hydrogeologic units, groundwater quality monitoring in the Keokuk Formation was not performed, as described in the *Physical Characterization Memorandum*. Groundwater quality monitoring from the upper two bedrock hydrogeologic units and the alluvium was performed. Five monitoring points were established in the Salem Formation. The base of the active sanitary landfill is adjacent to the Salem Formation. Salem Formation monitoring locations would be the first locations to detect releases from the active sanitary landfill. Even though available data indicate that all St. Louis/Upper Salem monitoring points are upgradient of the active landfill, 12 St. Louis/Upper Salem monitoring locations were sampled for groundwater quality. The St. Louis/Upper Salem is the uppermost bedrock unit at the site, and is present adjacent to the active sanitary landfill. Seven alluvial monitoring locations were sampled for groundwater quality. Detailed rationale for the selected monitoring locations is presented in the *Physical Characterization Memorandum*.

3.3.2 Drilling of Boreholes

Boreholes were sited in single, paired, or clustered locations (Figure 3-1). Single boreholes, and, in general, the deepest boreholes at paired or clustered piezometer locations, were sampled continuously to provide stratigraphic control. Shallower boreholes at the cluster locations were sampled across the proposed piezometer screen interval. Accordingly, borehole drilling methodology varied according to sampling requirements. Selected boreholes were logged geophysically and packer tested upon completion of drilling. Piezometers were subsequently installed in certain boreholes, surveyed for location and elevation, developed, and slug tested. Boreholes drilled through solid waste materials in the inactive landfill were completed as leachate risers where leachate was encountered. Other boreholes were backfilled with grout and abandoned. Drilling, sampling, and testing were supervised or performed by qualified personnel.

During drilling, air monitoring was performed to identify explosive conditions and potential breathing hazardous to site personnel. A MiniRae photoionization detector (PID) was used to monitor volatile organic vapors. A Bacharach Sentinel 44 was used to monitor explosive vapors, hydrogen sulfide, and oxygen. Monitoring procedures and action levels specified in the Site Health and Safety Plan were followed.

Unconsolidated Drilling

Boreholes drilled through unconsolidated materials (i.e., loess, alluvium, fill, or solid waste) were advanced using a Central Mining Equipment (CME) 75 drill rig with hollow stem augers until the target depth was reached or bedrock was encountered. All downhole equipment was decontaminated with high pressure potable water steam cleaner before drilling was initiated at each borehole.

Bedrock Drilling

Continuous sampling of the bedrock units was accomplished with the CMS 75 drill rig using diamond core drilling techniques. A triple tube, wireline 3.5-inch OD NX core drilling system was used. Shallow bedrock boreholes at paired or clustered locations where continuous sampling was not necessary were drilled with a 5 7/8-inch diameter button air percussion hammer bit to the top of the proposed piezometer screen depth, and then cored across the proposed screen interval. Coring in these boreholes was accomplished with the Schramm air drill rig using a double tube NX coring system. Potable water and/or filtered air were used as the drilling medium to remove the cuttings and advance the borehole.

During bedrock drilling, it was necessary to add water to the holes to cool the drill bit and facilitate coring. The source of the drill water was the municipal water supply to the concrete batch plant.

Drilling Techniques

Different drilling and sampling techniques were utilized depending upon the subsurface conditions encountered. The majority of drilling was accomplished with either 4.25-inch or 6.25-inch inside diameter (ID) hollow stem augers. Bentonite mud rotary techniques, utilizing a 3-inch diameter tricone bit, were used if saturated heaving sand deposits were encountered greater than or equal to ten feet in thickness. The bentonite mud was used to stabilize the borehole during drilling and sampling at boreholes PZ-113-AD, PZ-115-SS, PZ-300-AI, PZ-302-AI, PZ-304-AI, and PZ-305-AI. The bentonite mud was mixed and contained in portable mud tanks. Bentonite mud was also used to stabilize the borehole for installation of surface casing in the unconsolidated materials at boreholes PZ-105-SS, PZ-107-SS, PZ-111-SD, PZ-111-KS, PZ-115-SS, PZ-203-SS, PZ-205-SS, and PZ-300-SS. These boreholes were also drilled with 10.25-inch augers to allow for the installation of surface casings.

Surface casing was used at certain borehole locations to seal off loose or saturated alluvial deposits, isolate saturated flowing sands, or to isolate overlying formations prior to advancing the borehole into underlying formations. Surface casings were not required by the EPA-approved OU-2 Work Plan (Golder, 1995b). Use of the surface casings was deemed appropriate to provide additional environmental protection and to ensure representative data.

Field engineers determined after drilling PZ-100-KS that surface casings would be utilized in subsequent boreholes, where necessary, to isolate formations above the Warsaw Shale before penetrating unit. Surface casings were also installed in certain boreholes drilling into the Keokuk Formation, in order to isolate groundwater in aquifers overlying the low-permeability shales of the Warsaw Formation from groundwater in the underlying Keokuk Formation. Borehole logs (described below), piezometer construction summaries, and Table 3-1 identify boreholes constructed with surface casing.

Table 3-1 summarizes the surface casing sizes and depths at the individual borehole locations. Surface casing consisted of 20-foot lengths of steel pipe with either 6 1/8-inch ID/6 5/8-inch OD or 10-inch ID/10 7/8-inch OD specifications. The 10-inch ID casing was used in conjunction with the 6 1/8-inch casing in PZ-111-KS in a telescoping arrangement. The 10-inch casing was installed to a depth of about 98 feet to isolate fine alluvial sands, while the 6 1/8-inch casing was installed to a depth of about 215 feet to isolate formations above the Warsaw Formation.

Several drilling methods were used to install the steel surface casing. Bentonite mud rotary drilling was used to stabilize significant thicknesses of saturated alluvium prior to advancing the borehole into the underlying bedrock units. A Failing KC43 mud rotary drill rig was used in conjunction with a 14 3/40inch diameter tricone bit for installing the 10-inch steel casing. Either a 9 7/8-inch diameter tricone bit or a 10-inch diameter air percussion button but was used for installation of the 6-inch steel casing. Neat cement grout was tremied to the bottom of the annulus between the borehole wall and the steel casing to seal the borehole. The cement grout was, at a minimum, allowed to cure overnight prior to advancing the borehole below the casing.

Selected boreholes proposed in the Work Plan were deleted or moved, after notifying EPA and receiving verbal approval to do so. Representative of Maryon Industries (Asphalt Plant Operators) would not allow access to drill PZ-305-AS and PZ-305-AI on their leased property. Maryon Industries is currently remediating free product from underground storage tank releases in the area. The borehole from PZ-305-AI was moved farther east and adjacent to leachate riser LR-104. PZ-305-AS was not drilled. Leachate riser LR-104 should be considered a replacement for PZ-305-AS. Piezometer PZ-300-AI discussed in the Work Plan was not constructed because less than five feet of saturated alluvium was encountered above bedrock in adjacent boreholes PZ-300-AD and PZ-300-SS preventing isolation of saturated intervals in the alluvium.

Four piezometers along the eastern boundary of the landfill (PZ-200-SS, PZ-201-SS, PZ-202-SS, and PZ-203-SS) were intended to be constructed with long screened intervals, from about 10 feet below ground surface to total depth (Golder, 1995b). The Work Plan was modified to also construct PZ-204-SS as a long screened interval piezometer. These piezometers were designed to be used for both water level and landfill gas monitoring. However, anomalously high water level readings were obtained in PZ-201-SS subsequent to installation, suggesting the potential for a perched water zone. Two additional piezometers, PZ-201A-SS and PZ-204A-SS, were drilled and constructed with a nominal 10-foot long screened interval, placed at the same depth as the bottom of PZ-201-SS and PZ-204-SS, respectively. PZ-203-SS, which had not been drilled when the anomalously high water level readings were observed in PZ-201-SS, was constructed with the nominal 10-foot long screen interval. PZ-200-SS and PZ-202-SS were constructed with the long screened interval specified in the Work Plan.

PZ-102-SS exhibited bentonite in purge water during development, indicating suspect integrity. PZ-102R-SS was drilled and constructed adjacent to PZ-102-SS as a replacement piezometer.

Piezometer completion details were recorded on piezometer construction summaries, which are provided in Appendix E-1 of the *Physical Characterization Memorandum for West Lake Landfill OU-2*. MDNR Division of Geology and Land Survey Monitoring Well Certification Records were completed and are supplied in Appendix F of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*.

Alluvial piezometers PZ-300-AS and PZ-300-AD, bedrock piezometer PZ-300-SS, previously existing bedrock piezometers MW-1205 and MW-1206, and previously existing alluvial piezometers I-50 and S-80 were decommissioned in April 1996. PZ-300-AS, PZ-300-AD, PZ-300-SS, I-50 and S-80 were decommissioned due to impending property development. Verbal authorization was obtained from EPA prior to decommissioning. Monitoring wells MW-1205 and MW-1206 were part of the active landfill's groundwater monitoring system and were decommissioned to accommodate filling sequences. The State of Missouri provided authorization to decommission monitoring wells MW-1205 and MW-1206. The piezometers and wells were decommissioned in accordance with State of Missouri procedures, which include drilling out the well material and backfilling the hole with low permeability materials. The surface casing that had been installed through the alluvium in PZ-300-SS to isolate the bedrock monitoring zone was left in place and filled with low permeability grout. A variance was granted by the State of Missouri allowing this casing to remain in place.

One existing monitoring well, MW-1201, had been originally completed as an open borehole monitoring well. As part of this investigation, MW-1201 was modified to the MDNR specifications for monitoring wells, similar to the newly-installed piezometers. The monitoring well was backfilled with bentonite grout (consistent with Missouri Well Construction Rules). The bentonite grout/cement grout plug was extended from the MW-1201 original completion depth of 250 feet to a depth of 148.5 feet. The borehole was then completed as a piezometer in accordance with the procedures described below. The new depth is consistent with other piezometers completed in the St. Louis and upper portion of the Salem Formations. Accordingly, the new piezometer was designated PZ-1201-SS.

Subsurface Sampling

Subsurface samples were collected during borehole drilling to identify the stratigraphic characteristics of unconsolidated materials and bedrock. Sampling equipment was decontaminated with Liquinox™ (or a comparable solution) and rinsed with potable water between each use. After air drying, the equipment was rinsed with distilled or deionized water. All cleaned or unused sampling equipment was handled by personnel wearing disposable latex gloves. The decontaminated sampling equipment was stored in plastic bags or sheeting. As specified in the Work Plan, water used for decontamination activities was disposed of in the leachate retention pond located southwest of the site.

The unconsolidated materials were continuously sampled using standard 1.5-inch ID by 2.0-foot long split spoon samplers. The split spoon samplers were advanced below the augers with either an automatic or semi-automatic hammer dropping system which lifted a 140-pound hammer approximately 30 inches. The number of blows required to advance the sampler in 6-inch intervals over the 2-foot length were recorded. At designated boreholes and intervals, 2 13/16-inch ID/3.0-inch outside diameter (OD) by 2.5-foot long Shelby tube and California barrel were used to collect undisturbed soil samples.

As part of the subsurface investigation, four soil borings were drilled at the southwest corner of the inactive landfill (Figure 3-1). The boreholes were drilled to define the extent of potential hydrocarbon impact to the soils adjacent to existing well MW-F2. The soil borings were sampled continuously with split spoon samplers. The borings were terminated at the water table, which was identified from 13 to 18 feet below ground surface.

In addition to the soil testing conducted at the laboratory, two siltstone core samples (GTS-1 and GTS-2) were sent to Advanced Terra Testing of Lakewood, Colorado for vertical permeability testing. These samples were collected from near the top of the Warsaw Formation in PZ-106-KS. Laboratory results for these samples are included in Appendix D of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*.

All soil samples were photographed, visually described, an then placed in labeled Ziplock™ plastic storage bags. The samples were described to the Unified Soil Classification System (USCS) and descriptions were recorded on soil borehole logs. The logs are presented in Appendix A of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*. The soil borehole logs include the geologic origin (if appropriate), blow counts, sample recovery, color (Munsell Rock Color Chart), material description, and classification according to the USCS using ASTM Methods D2487 and D2489. Table 3-3 identifies USCS classification symbols utilized in the logs.

Rock core was placed in wooden core boxes after logging. The stratigraphic orientation of the core was indicated, and each core box was labeled with an indelible marker with the project name and/or number, the box number, and the depth at the start and end of the core contained in the box. All rock core was photographed. At the conclusion of drilling, the core boxes were stored in a building at the site.

Drillhole Logs

The record of drillhole logs are provided in Appendix A of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2* and include descriptions of the geologic characteristics of the rock core. Graphic logs depict lithology and fracture orientation (relative to the core axis), with discontinuities described according to type, shape, and surface characteristics. Table 3-3 identifies rock symbols utilized in the logs and describes the basic characteristics logged by field personnel. The rock descriptions are as follows:

- Weathering – Classification according to International Society for Rock Mechanics (IRSM) standard and qualitative description of any unusual weathering characteristics.
- Structure – Any persistent structure in rock such as foliation, flow banding, bedding, lamination, grading, sorting, etc., and dip specification with respect to the core axis.
- Color – Color name from Geologic Society of America Munsell Color Chart of wet rock. If rock in composed of more than one color, major colors starting with the most prominent are listed.
- Grain or Crystal Size – Size of visible grains or crystals in millimeters or according to the Wentworth scale.

- Strength – Field estimate of intact strength based on ISRM classification. Qualitative description of factors that might affect strength such as weak layers and any seams.
- Rock Type – Basic rock type as recognized by Colorado School of Mines Classification System (Travis, 1995).

Geotechnical parameters were also recorded and include core recovery, fracture frequency, rock strength, and Rock Quality Designation (RQD). RQD is a modified core recovery in which only the sound core recovered in lengths greater than four inches (measured along the core axis) is counted as recovery. RQD is expressed as the percentage of total length of intact core recovered in lengths greater than 4 inches over the total length of the core run. The RQD percentage can then be used to describe the rock quality.

After the borehole had been drilled to final depth, the borehole was reamed with 5 7/8-inch diameter air percussion button hammer bit using air rotary drilling techniques. The boreholes were reamed to allow downhole geophysical testing, packer testing, and piezometer installation.

Leachate Borings

Drilling methodology for solid waste borings in the inactive landfill areas was similar to the subsurface drilling methods described previously. Drilling was conducted with a 4.25-inch ID hollow stem augers. Samples of the solid waste were typically collected with a California Barrel sampler. The borehole logs designated as LR-100 through LR-105 are presented in Appendix A of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*. The boreholes were advanced until either a potential confining layer or the base of the landfill was encountered. At the completion of drilling, the depth to fluid was measured within the hollow stem augers and recorded on the borehole logs.

Piezometers were constructed according to Missouri Department of Natural Resources (MDNR) Well Construction Rules for monitoring wells (MDNR, 1993). All downhole equipment was decontaminated prior to piezometer installation, and the piezometers were constructed using either factory-cleaned and wrapped materials, or site-decontaminated materials. In either case, all downhole equipment and materials were handled by personnel wearing clean (new) disposable latex gloves. Decontamination water was disposed of in the leachate retention pond. Typical piezometer construction details are depicted in Figure 3-2. Piezometers were constructed with 2-inch diameter, nominal 10-feet long (typical) flush threaded Schedule 80 polyvinyl chloride (PVC) casing. Each casing joint was fitted with O-rings to prevent leakage. The riser pipes extend to approximately 1.5 feet above ground surface. Vented PVC slip caps were placed over the top of the risers. Screened intervals generally consisted of nominal 10-foot long Schedule 80 PVC screens with 0.010-inch machine cut slots. A flush threaded endcap, approximately 4-inches long, was attached to the base of each screened interval as a sump to collect any sediments migrating into the piezometer and to prevent blockage of the screened interval.

Piezometers completed in alluvium were generally constructed within the hollow stem augers as the augers were retracted from the borehole. Bedrock piezometers were constructed within the open boreholes after reaming core-drilled sections with 5 7/8-inch diameter air percussion button bit to yield a nominal 6-inch diameter borehole. Stainless steel centralizers were used in piezometers constructed in bedrock. The centralizers were placed at approximately 40-foot intervals to maintain the riser in the center of the borehole, consistent with Missouri Well Construction Rules published at CSR 23-4.060(7) (MDNR, 1993).

After lowering the PVC screen and riser pipe into the borehole, a primary filter pack, consisting of 16/35 mesh environmental grade silica sand, was placed into the annular space of the borehole. 16/35 sand has a gradation of 90 percent passing the number 16 US Standard Sieve size and 90 percent retained by the number 35 US Standard Sieve size. The primary filter pack generally extended at least 2 feet above the top of the screened interval. During primary filter placement in the piezometers constructed in the alluvium, hollow stem augers were slowly withdrawn to prevent collapse of the borehole. For both the bedrock and alluvium piezometers, the rate of sand flow into the borehole was restricted to allow for settlement and reduce the potential for bridging.

In piezometers constructed with the primary filter pack within the saturated zone, a secondary filter pack was placed over the primary filter pack to minimize the potential for the bentonite seal or grout to penetrate the primary filter pack. The secondary filter pack consists of a 0.5- to 2.0-foot thick layer of less than 50 mesh environmental grade silica sand. A tremie pipe was used to place the filter packs below the water table.

Surface completion consisted of installing an 8-inch square, 5-foot long steel protective casing over the PVC riser. The potential cover was placed into approximately 3 feet of concrete. The concrete pad was constructed around the protective cover and sloped away from the cover to promote drainage. In general, the aboveground portion of the pad was 3 feet by 3 feet square. The annular space between the protective cover and the riser pipe was filled with bentonite chips to ground surface, above which ¼-inch pea gravel was placed to within 6-inches of the top of the riser. A weep hole was drilled at the base of each protective to provide an outlet for any water which may be introduced inside the protective cover. Metal bumper posts (3 inches in diameter by 6 feet long) were placed around each piezometer located in a high traffic area. The protective covers were labeled with the appropriate piezometer designation and fitted with keyed-alike locks.

Geophysical Logging

Geophysical logging of selected boreholes was performed to correlate and verify rock core logging. Geophysical logging also allows estimation of aquifer properties such as porosity and permeability.

Geophysical logging was performed in the four piezometer borehole clusters which penetrated the Keokuk Formation (boreholes PZ-100-KS, PZ-104-SD, PZ-104-KS, PZ-106-SD, PZ-106-KS, PZ-111-SD, PZ-111-KS, and MW-1201). Borehole MW-1201 (renamed PZ-1201-SS) was logged prior to installation of piezometers casing and sealing of the borehole. Wooddell Logging, Inc. (Wooddell) of Matoon, Illinois, was subcontracted to perform borehole geophysical logging. Each borehole, with the exceptions described below, was logged using natural gamma ray, caliper, point resistivity, gamma-gamma (bulk density), neutron, and spontaneous potential (SP) tools. Wooddell prepared a report describing their logging tools, methods, and basic interpretation of data (Appendix B of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*). The geophysical logs are also provided in Appendix B of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2.*

At PZ-100-KS, the borehole was logged using the natural gamma ray tool, caliper, resistivity tool, and gamma-gamma tool. In addition, a drift survey tool was used at this location to determine the actual borehole alignment. At MW-1201, only the calipher and natural gamma ray tools were used.

At three of the four clusters (i.e., PZ-104, PZ-106, and PZ-111), geophysical logging was conducted in the "SD" boreholes from ground surface to the top of the Warsaw Formation and at the "KS" boreholes from the top of the Warsaw Formation to total depth. Logging was performed in two boreholes at these locations because 6-inch steel casing had been installed to the top of the Warsaw Formation in the "KS" boreholes, preventing the subsequent use of geophysical logging equipment.

A brief description of each geophysical logging tool is provided below; detailed descriptions are contained in Wooddell's report.

- Natural Gamma Ray tool:
  - Measures natural radiation of formation continuously.
  - Shales, clays, and clayey materials contain the greatest concentrations of radioactive isotopes.
  - Primarily used to distinguish clay and shale units from other materials, bed definition, determination of interfaces, and correlation.
- Calipher tool:
  - Measures the actual borehole diameter.
- Resistivity tool:
  - Indication of the water quality by measuring the apparent resistivity of the materials surrounding the borehole.
  - Provides a detailed picture of the character and thickness of various strata in the borehole.
- Gamma-Gamma tool:
  - Determination of formation density.
  - Indication of porosity. Generally, as the density increases, the porosity decreases.
- Neutron tool:
  - Indication of total porosity under saturated conditions.
  - Measures amount of hydrogen ions in the formation which generally indicates the amount of water present.
- Spontaneous Potential tool:
  - Measures natural occurring electrical potentials (voltages) that result from chemical and physical changes at the contacts between different subsurface materials.
  - Used to establish a shale or clay baseline as generally more permeable strata will have little or no shale and/or clay.

Geotechnical laboratory results

Geotechnical laboratory test results of unconsolidated materials are summarized in Table 3-4. Laboratory testing was performed to estimate natural moisture content values for 19 soil samples. The value of natural moisture content ranged from 14.0 to 37.4 percent.

Specific gravity values were obtained for 28 samples. Values for specific gravity range from 2.51 to 2.81, with a mean value of 2.69. Specific gravity is a unit-less value. The specific gravity values were used in conjunction with the hydrometer tests to determine the particle size distribution of the materials finer than the 200 mesh sieve. Particle size distribution curves are provided in Appendix D of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2.*

Thirty-two samples were submitted for Atterburg Limit tests. However, nine of the samples were determined to be non-plastic and were classified as ML (silt), SP (poorly graded sand), SM (sandy silt) according to USCS. The liquid limits of the 23 remaining samples ranged from 31 to 80 percent. The plasticity index ranged from 8 to 29 percent. These results indicate a predominance of clay in the samples. Fourteen of the samples were classified as CL (clay), one was classified as CH (clay), one was classified as ML (silt), and two were classified as CL-ML (clayey-silt).

Laboratory flexible wall permeability tests were also performed on selected samples (Table 3-5). Permeability for soil samples was found to range between 2×10^{-7} centimeters per second (cm/sec) and 2×10^{-4} cm/sec. These results are discussed further in Section 3.5.2.3.

However, the results of the physical characterization indicate that wells completed in the bedrock aquifers underlying the site generally yield very little water (<5gpm).

3.4 Geologic Formations

Geologic formations encountered during the OU-2 RI are discussed below. Geologic cross sections were developed at the locations shown in Figure 3-3. The cross sections depict vertical and horizontal distribution of these units in Figures 3-4 through 3-7.

3.4.1 Keokuk Formation

Four boreholes penetrated into the Keokuk Formation. Based on information obtained from these boreholes, the Keokuk Formation beneath the Site was generally identified as a fresh to slightly or moderately weathered, thin- to medium-bedded, very light gray to light olive, medium- to coarse-grained, medium strong, fossiliferous limestone (Golder, 1996). Dolomite and dolomitic limestone beds as well as chert layers and nodules were observed to be present with the Keokuk Formation. The limestone units of the Keokuk Formation were variously described as siliceous and arenaceous (sandy) as well as porous and vuggy.

Fractures were infrequently (generally less than two fractures per foot) identified in the Keokuk Formation and were generally described as irregular and rough. Some fractures were reported to be bedded and planar. Open vugs and/or porous zones were identified in the lower portion of the formation below an elevation of 100 feet above mean sea level (AMSL).

The Keokuk Formation was encountered in the site boreholes at depths of 365 to 375 feet below ground surface along the eastern edge of the active sanitary landfill at elevations ranging from 115 to 126 feet AMSL. Along the western edge of the active sanitary landfill, the Keokuk Formation was encountered at depths of approximately 345 feet below ground surface (elevation of 115 feet AMSL). The structural surface of the Keokuk Formation is depicted in Figure 3-8.

3.4.2 Warsaw Formation

The Warsaw Formation was generally described as being a fresh and thickly bedded limestone with numerous beds of calcareous claystone and fossiliferous limestone beneath the site (Golder, 1996). Various portions of the Warsaw Formation were described as arenaceous (sandy) or argillaceous (clayey). Many interbeds of dolomite, claystone, siltstone, clayey siltstone, and silty claystone were also observed to be present. The limestone beds were very fine- to very coarse-grained or micro- to coarsely crystalline ranging in color from dark greenish gray to olive black. The beds of this formation were characterized by vuggy porosity.

The lower portion of the Warsaw Formation is reported to consist primarily of thin- to medium-bedded limestone, which includes thin chert layers and small chert nodules. The lower portion of the Warsaw Formation grades into the upper sand portion of the Keokuk Formation. The upper portion of the Warsaw Formation was characterized by a 2.5 to 10 foot thick claystone or siltstone layer commonly referred to as the Warsaw Shale.

Fractures in the Warsaw Formation were rare and generally did not exceed a frequency of one fracture per foot. Fractures observed were reported to be generally jointed, irregular or planar, and rough or smooth. Clay infilling of joints was common.

The Warsaw Formation was encountered at about 245 feet below ground surface (approximately 240 feet MSL elevation) near the eastern edge of the active sanitary landfill. Along the western active sanitary landfill edge, the Warsaw Formation was encountered at depths ranging from about 200 to 210 feet below ground surface, equivalent to about 250 to 260 feet MSL elevation. These elevations roughly correspond to the base of the old quarry pit (Midwest Environmental, 1994), indicating that quarrying terminated at the top of the Warsaw Formation. The unit thickness ranged from about 130 to 145 feet. The structural surface of the Warsaw Formation is depicted in Figure 3-9.

Regional descriptions of the Warsaw Formation identify the argillaceous (clay) content of this unit as characteristic of the upper portion (Thompson, 1986 and Howe, 1961). The argillaceous content was apparently derived from sources to the east, in the Illinois basin. The lower portions of the formation are described as principally composed of finely to coarsely crystalline, fossiliferous limestone.

3.4.3 Salem Formation

The Salem Formation at the site was generally identified as a fresh, thinly- to thickly-bedded, medium strong limestone. The color of the formation was typically described as pale yellowish brown to light olive gray. The limestone was variously described as argillaceous or arenaceous, bioclastic, fossiliferous, or fossiliferous dolomitic limestone. Interbedded dolomite layers were common, and chert clasts, nodules, and layers were scattered throughout the formation at varying frequencies. In general, the geophysical logs confirmed the visual classifications and descriptions of the Record of Drillhole logs.

Fractures were rare in the Salem Formation. The lower portion of the formation generally exhibited zero to one fracture per foot. The upper portion of the formation generally exhibited up to two fractures per foot. The fractures were characterized as jointed, irregular, and rough; or, as jointed, planar, and smooth.

The Salem Formation was encountered at a depth of about 165 feet along the eastern edge of the sanitary landfill (about 320 feet MSL elevation). Depth to the formation along the western active sanitary landfill ranged from 115 to 135 feet, with the formation surface elevation between 328 and 340 feet MSL elevation. The thickness of the Salem Formation ranged between 67 and 83 feet. The structural surface of the Salem Formation is depicted in Figure 3-10.

Regional descriptions of the Salem Formation emphasize the dolomitic and fossiliferous nature of the limestone (Thompson, 1986 and Howe, 1961). Regionally, the top of the formation grades conformably upward into the St. Louis Formation, and the intermediate beds contain coral, foraminifera, and echinoderm fossils and fragments. The upper 50 feet of the Salem in the St. Louis area contains a high percentage of speckled gray and tan chert. As noted above, the Salem Formation beneath the site included chert nodules and layers throughout its thickness.

3.4.4 St. Louis Formation

The St. Louis Formation was generally described from core samples as interbedded fresh to slightly weathered limestone and dolomite. The unit grades into the underlying Salem Formation. Bedding ranged from thin to very thick, and color ranged from very light gray to olive gray. The unit was typically classified as fine to medium crystalline or fine- to medium-grained, and medium strong. The limestone beds were variously characterized as arenaceous, argillaceous, dolomitic, or clastic. Claystone and siltstone beds and layers were periodically observed. Chert was not commonly identified. In general, the geophysical logs confirmed the visual classification and descriptions of the Record of Drillhole logs.

Fracturing ranged from zero to ten fractures per foot, and the fractures were generally classified as joints, irregular, or rough. Fractures were generally infilled with clay. Stylolitic joints were also observed.

Depth to the St. Louis Formation ranges from about 14 to 52 feet below ground surface along the eastern edge of the active sanitary landfill, and between 20 and 110 feet below ground surface along the western edge of the active sanitary landfill. The top of the St. Louis Formation ranges between about 425 and 460 feet MSL elevation in the eastern portion of the site, and between 379 to 442 feet MSL elevation in the western portion of the site. This variation reflects the buried edge of the Missouri River valley and the limestone bluffs upon which the quarry was sited. The thickness of the St. Louis Formation ranges from about 65 to 130 feet. The structural surface of the St. Louis Formation is depicted in Figure 3-11. The approximate location of the edge of the alluvial valley is also indicated on Figure 2-2.

3.4.5 Cheltenham Formation

The Cheltenham Formation was only encountered near the surface at PZ-301-SS. Literature describes the formation as consisting of clays and associated clastics, lying above Ordovician-to-Mississippian-aged strata and below Pennsylvanian-aged strata. The clays are mostly white to light- or medium-gray to purplish or red (Thompson, 1995). Thin coal beds are also present in the formation.

At PZ-301-SS, the Cheltenham Formation was identified from 19.1 to 71.5 feet below grade. The surrounding area had previously been excavated and lies within the former landfill borrow area. The formation was generally described from core samples as predominantly olive to greenish gray to light brownish gray claystone. Thin limestone, siltstone, and coal beds were identified. With the exception of the upper 10 feet of the formation, the core was relatively unfractured.

3.4.6 Unconsolidated Materials

Quarternary deposits in the region are comprised of recent (Holocene) alluvial deposits from the Missouri River, and upland loess and glacial till deposits from Pleistocene glaciation. The alluvial deposits range in thickness from 0 to 150 feet. Loessial deposits are up to 100 feet thick, and glacial till deposits are infrequent but occur in layers up to 55 feet thick. Near the site, the overall thickness of the alluvium varies from absent to greater than 100 feet beneath the center of the Missouri River valley, 2 miles west.

The loess is an aeolian (windblown) deposit and consists primarily of silt and clay. The loess was deposited as a blanket over much of northern Missouri and Illinois during the Pleistocene glacial epoch. The bluffs and hills immediately east of the site are composed of loess in deposits up to 80 feet thick.

Unconsolidated materials at the site consist primarily of alluvium and loess. The surficial loess at the site was redeposited during the late Pleistocene. Silt was picked up from the braided glacial melt-out drainages by westerly winds. The thickness of these loessial deposits is greatest in the eastern regions of the drainages and diminishes rapidly to the west. Thus, the bluffs and hills immediately east of the site are composed of loess in deposits up to 80-feet thick, but the loess deposits directly adjacent to the quarry at the site are relatively thin (Thompson, 1986). Loess was identified as silty clay and clayey silt in deposits from 13 to 22 feet thick along the eastern edge of the active sanitary landfill. Underlying alluvial deposits, when present, range from silty clay and clayey silt to sand, and ranged from 12 to 32 feet thick.

Loess was not commonly encountered along the western edge of the active sanitary landfill. Where encountered, loess deposits in the western portion of the site were about 10 to 15 feet thick, and occasionally interbedded with alluvial deposits. The alluvial deposits along the western edge of the site ranged in thickness up to about 120 feet. The thickness of the alluvial deposits and the depth to top of bedrock increased to the west, indicating the presence of the alluvial valley. Alluvial deposits typically consisted of fine-grained (clay and silt) materials overlying coarse-grained (sand and gravel) materials. The silt and clay are derived from periodic flooding of the Missouri River (overbank deposits). The coarse-grained materials are point bar deposits, and were identified as predominantly poorly-sorted sands. The thickness of the unconsolidated materials, and the edge of the alluvial valley is depicted in Figure 3-12.

3.5 Groundwater Investigation

3.5.1 Monitoring Well Development

The completed piezometers were initially developed using both surge block, bailing, and airlift techniques. The drill crew surged the piezometers with stainless steel surge block for about one hour, followed by about two hours of a combination of bailing and air lifting. Airlifting was performed using an air compressor fitted with a filter to remove moisture and lubrication oil. A J-tube was used to discharge the compressed air inside ¾-inch, threaded PVC pipe which lifted the development water to the surface. All downhole equipment was decontaminated prior to development activities at each piezometer; decontamination water was disposed of in the leachate retention pond.

A second stage of development was performed using bailers. New polyethylene rope was used at each piezometer. The bailers were decontaminated between piezometers using Liquinox™, tap water rinse, and final deionized water rinse. Personnel wore new disposable latex gloves when developing each piezometer.

Piezometers were developed sufficiently to remove sediments, thereby providing confident slug testing and water level elevation results. Piezometer development data is summarized in Appendix G of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*. The development water was contained during development and was disposed of in the leachate retention pond. In addition, all piezometers were purged prior to groundwater sample collection. The development and purging activities were conducted to allow collection of representative groundwater samples.

3.5.2 Packer Testing, Slug Testing and Laboratory Testing

In-situ packer and slug tests, and laboratory permeability tests, were performed as part of the recent investigation. Packer testing was performed using a constant head test method, slug tests were performed using primarily a rising head method, and laboratory testing was performed using a triaxial permeability test method. Packer tests were performed on both saturated and unsaturated bedrock units, while slug tests and laboratory permeability tests were performed only on saturated units.

3.5.2.1 Packer Testing

Aquifer testing was performed in selected open boreholes by conductivity packer tests. The packer test results were used to determine the hydraulic conductivity in the test zones of the Keokuk, Warsaw, Salem, and St. Louis Formations. Constant head injection packer tests were performed in the four Keokuk Formation boreholes (PZ-100-KS, PZ-104-KS, PZ-106-KS, and PZ-111-KS) and three deep adjacent Salem Formation boreholes (PZ-104-SD, PZ-106-SD, and PZ-111-SD) prior to construction of piezometers. The packer test activities were supervised and performed by qualified field personnel.

Hydrologic packer testing was performed using a downhole packer assembly with associated surface equipment. Both double (straddle) and single packer systems were used for testing within the boreholes. Information such as the test number, depth, geologic formation, single or double packer test, and other pertinent test data is included in Appendix C-1 of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*.

Packer test zones were selected using the rock core and geophysical log information collected during advancement of the corehole and subsequent corehole reaming. The test intervals were selected by isolating zones which appeared to be:

- Relatively fractured;
- Relatively unfractured;
- Relatively porous; or,
- Relatively non-porous.

In this manner, a range of hydraulic conductivity values was obtained for each of the units.

Single packer tests were applied using a single pneumatic packer set at the top of the test interval and the bottom of the borehole as the lower point of test confinement. Double packer tests were performed using pneumatic straddle packers set around the selected test zones within the borehole. Double packer tests generally tested 5-foot intervals of borehole.

The single and double packer assemblies, consisting of one or two sliding-end pneumatic packer(s) connected to a perforated pipe, were used in conjunction with surface control equipment to perform the hydrologic packer testing. The surface assembly consisted of a variable rate water pump for controlling water injection, a flow meter manifold, a pressure gauge, valving, and hoses. Drill rods were used to lower the packer assembly into the borehole and provide a conduit for water injection. The borehole packer assembly was raised and lowered within the borehole using an air drill rig.

Flow rates into the test interval were stepped up incrementally and held steady for approximately 10 minutes to allow the pressure within the test zone to stabilize. Estimates of hydraulic conductivity were calculated using a constant head analysis method. To apply the constant head test method, the test interval was pressurized by injecting water, while the flow response, and the pressure response (head) in the test interval were monitored. The field testing procedure that was employed is summarized as follows:

- Measure tool assembly and drill rod lengths;
- Measure the depth to water below the ground surface;
- Lower packer assembly to the prescribed depth;
- Measure drill rod stick-up to ensure that the packer(s) is at the correct depth;
- Fill test system with fresh (potable) water;
- Inflate packers with downhole valve open and surface flow valves closed (minimum 150 psi to 350 psi for 6.0-inch diameter hole);
- Open surface flow valves on flow meter manifold to pressurize test interval with water;
- Check system for leakage and bleed air out of system, if necessary;
- Monitor flow rate and interval pressure until both are nearly constant;
- Perform multiple pressure steps and flow rate increases (typically three up and one down); and,
- Deflate packers and stop test.

Several steps (flow rate increases) were usually applied to the test zone to allow elimination of hydraulic conductivity at different pressures (heads) and respective flow rates. However, multiple steps were not always completed because some test zones required very high pressures to induce flow, or exhibited acceptable, minimum flow at very low pressure. In general, water was injected until a flow rate was established, and stabilized pressures (for head) within the test intervals could be predicted. Under these conditions, a steady flow analysis method is applicable (Logan, 1964), and:

$$K = \frac{Q}{2\pi LH} \ln(R / r_w)$$

Where:

K = Average hydraulic conductivity or the test interval (L/T);
Q = Steady state flow rate (L3/T);
L = Test interval length (L);
H = Constant head differential (constant head above static) imposed on the interval (L);
R = Radius of the pressure boundary (L); and,
r_w = Radius of the corehole (L).

The constant head test method was successfully applied to test intervals in selected open coreholes (i.e., PZ-100-KS, PZ-104-SD, PZ-104-KS, PZ-106-SD, PZ-106-KS, PZ-111-SD, and PZ-111-KS). The double packer test interval lengths were set at five feet, while the single packer test intervals ranged from 10 feet to 148 feet. Analysis was conducted on data collected from tests performed on both saturated and unsaturated intervals. Results from tests performed in the unsaturated intervals have been reported as intrinsic permeability (i.e., permeability to air), while tests performed in the saturated intervals have been reported as hydraulic conductivity. The results are presented in these units since intrinsic permeability is a function of the flow medium while hydraulic conductivity is a function of both the flow medium and fluid (i.e., water). Tests were performed in the unsaturated intervals to allow for landfill operator to separately calculate landfill gas migration, while tests in the saturated intervals were performed to augment groundwater flow calculations. Parameters used to estimate the intrinsic permeability and hydraulic conductivity tests are provided in Appendix C of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*. A summary of packer testing results is included as Table 3-6 (Keokuk Formation), 3-7 (Warsaw Formation), 3-8 (Salem Formation) and 3-9 (St. Louis Formation).

Keokuk Formation

The constant head test analysis for tests completed in the Keokuk Formation (Table 3-6) resulted in hydraulic conductivity values ranging from 7.6×10^{-7} cm/sec to about 4.3×10^{-5} cm/sec for the tested intervals. The geometric mean hydraulic conductivity was calculated to be 9.7×10^{-6} cm/sec. Although the Keokuk Formation tests resulted in the highest geometric mean hydraulic conductivity of the three formation units, this mean hydraulic conductivity value is low.

Warsaw Formation

The constant head test analysis for the Warsaw Formation tests (Table 3-7) resulted in hydraulic conductivity values ranging from 2.6×10^{-7} cm/sec to about 5.6×10^{-5} cm/sec for the tested intervals. The geometric mean hydraulic conductivity for the Warsaw Formation tests was calculated to be 2.6×10^{-6} cm/sec. Some packer tests conducted in the Warsaw Formation included the upper portion of the Keokuk Formation. Warsaw Formation hydraulic conductivity values for these tests were calculated by subtracting the Keokuk Formation contribution to the hydraulic conductivity value from the entire test interval, using the following equation (Todd, 1980):

$$K_{xt} = \frac{(K_1 Z_1 + K_2 Z_2)}{Z_1 + Z_2}$$

Where:

K_{xt} = Hydraulic conductivity for entire test interval;
K_1 = Hydraulic conductivity of Warsaw Formation portion of test interval (unknown);
K_2 = Hydraulic conductivity of Keokuk Formation portion of test interval ;
Z_1 = Length of Warsaw Formation portion of test interval ; and,
Z_2 = Length of Keokuk Formation portion of test interval.

Salem Formation

The constant head test analysis for the Salem Formation (Table 3-8) resulted in hydraulic conductivity values ranging from about 5.8×10^{-8} cm/sec to about 2.5×10^{-5} cm/sec, with a calculated geometric mean of 1.6×10^{-6} cm/sec.

St. Louis Formation

The constant head test analysis for the saturated interval tests in the St. Louis Formation (Table 3-9) resulted in hydraulic conductivity values ranging from 3.7×10^{-7} cm/sec to 4.4×10^{-6} cm/sec. The geometric mean hydraulic conductivity value for the saturated interval of the St. Louis Formation is 9.6×10^{-7} cm/sec.

The constant head test analysis for the St. Louis Formation unsaturated interval tests resulted in intrinsic permeability values ranging from 1.5×10^{-12} centimeters squared (cm^2) to about 7.5×10^{-9} cm^2 for the tested intervals. The highest intrinsic permeability value was measured near the loess/bedrock contact at PZ-100-KS. Other than the highest value measure at PZ-100-KS, these values are low and indicate that the bedrock will restrict the migration of landfill gas. The geometric intrinsic permeability of the unsaturated interval was calculated to be 4.9×10^{-11} cm^2.

3.5.2.2 Slug Testing

The newly installed piezometers were slug tested to evaluate the in-situ hydraulic conductivity of the different geologic formations present at the site. An initial water level measurement was taken prior to starting the test. An instantaneous rise or fall in water level was created by rapidly inserting or extracting a stainless steel rod (slug) into the water column. If the pre-test water level was above the screen interval, the rod was rapidly inserted into the piezometer to increase the water level. In piezometers where the screened interval intersected the water column, bailing was used to induce a water level change and provide for a rising head test. Changes in the water level were monitored with a pressure transducer/data logger or manually with an electronic water level indicator.

The water level recovery was monitored until the water level in the piezometer recovered a minimum of 70 percent of its initial (static) water level. If the piezometer recovered at least 90 percent of its static level within 30 minutes, the rod was quickly removed and the rising water level was monitored until 70 percent recovery was achieved.

Hydraulic conductivity values have been calculated using data obtained from slug tests performed in piezometers completed in the Keokuk Formation, the deep portion of the Salem Formation, the St. Louis/Upper Salem hydrologic unit, and the alluvium. The calculated hydraulic conductivity values from slug tests estimated for each of the piezometers tested are summarized in Table 3-10. Hydraulic Conductivity values shown on the table were calculated using the methods developed by Hvorslev (1951), Bouwer and Rice (1976), and Cooper-Papadopulos (1967). Where slug tests were conducted in piezometers prior to static water levels being reached, and when falling head slug tests were conducted within the sand pack, the results of the tests are shown on the tables, but have not been included in geometric means used for subsequent calculations; nor are results of these tests included in the permeability ranges presented below.

For the Keokuk Formation, the calculated Cooper-Papadopulos hydraulic conductivity ranges from 6.0×10^{-7} cm/sec to 3.8×10^{-6} cm/sec, with a geometric mean value of 2.1×10^{-6} cm/sec. This value is within the range of the geometric mean hydraulic conductivity values calculated from the packer tests analysis.

The hydraulic conductivity values for the slug-tested piezometers completed in the deep portion of the Salem Formation ranged between 1.0×10^{-7} cm/sec and 1.8×10^{-5} cm/sec for the Hvorslev analysis, and between 6.8×10^{-8} cm/sec and 1.2×10^{-5} cm/sec for the Bouwer and Rice analyses. The geometric mean hydraulic conductivity values were 8.4×10^{-7} (Hvorslev) and 5.4×10^{-7} (Bouwer and Rice), with a combined geometric mean value of 6.9×10^{-7} cm/sec.

The hydraulic conductivity values from slug tests in the piezometers completed in the St. Louis/Upper Salem hydrologic unit ranged from about 1.7×10^{-8} cm/sec to 3.0×10^{-3} cm/sec, with a calculated Hvorslev geometric mean of 3.0×10^{-6} cm/sec and a calculated Bouwer and Rice geometric mean of 1.2×10^{-6} cm/sec. The mean of both methods was calculated to be 1.1×10^{-6} cm/sec. These values confirm the packer test hydraulic conductivity values.

The geometric mean of hydraulic conductivity values for the tests conducted in the deep alluvial piezometers were 6.7×10^{-4} cm/sec for the Hvorslev analysis and 5.0×10^{-4} cm/sec for the Bouwer and Rice analysis. The geometric mean hydraulic conductivity value for the combined tests was calculated to be 5.9×10^{-4} cm/sec.

The geometric mean of hydraulic conductivity values for the test conducted in the intermediate alluvial piezometers were 1.8×10^{-2} cm/sec for the Hvorslev analysis and 1.2×10^{-2} cm/sec for the Bouwer and Rice analysis. The geometric mean hydraulic conductivity for the combined tests was calculated to be 1.5×10^{-2} cm/sec.

For shallow alluvial piezometers, the calculated Hvorslev geometric mean hydraulic conductivity is 2.5×10^{-3} cm/sec and the calculated Bouwer and Rice geometric mean hydraulic conductivity is 3.9×10^{-3} cm/sec. Bouwer and Rice analyses were not performed for several of the slug tests in this group where Bouwer and Rice analysis were inappropriate. The mean value of both tests is 2.9×10^{-3} cm/sec.

3.5.2.3 Laboratory Permeability Testing

Geotechnical laboratory soil sampling was performed at the Golder soils laboratory in Denver, Colorado on representative samples to supplement field observations and to further characterize the site soils. Samples were tested in accordance with standard ASTM methods. Laboratory tests performed included:

- Grain size;
- Natural moisture content;
- Liquid and plastic limits; and,
- Permeability testing of both undisturbed and remolded samples.

The laboratory data sheets are presented in Appendix D of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2.*

Thirteen laboratory permeability tests were performed to determine the vertical permeability of both undisturbed soil and bedrock samples, as well as remolded soil samples. Of the 13 tests, nine were performed on relatively undisturbed, field preserved Shelby tube soil samples. Two additional permeability tests were performed on recompacted, remolded soil samples. Finally, two tests were performed to determine the vertical permeability of two samples collected near the top of the Warsaw Formation.

The remolded soil samples were designated as PS-1 and PS-2. Sample PS-1 was collected from a loess deposit in the active borrow area south of the site, sample PS-2 was collected in the field northeast of the active sanitary landfill, in an area to be used for run-on surface control. The remolded soil samples were tested at approximately 95 percent compaction at the optimum moisture content. The samples were consolidated with a confining pressure of 5 psi and were allowed to saturate prior to testing.

The mean from the two Warsaw Formation rock core samples submitted for vertical permeability analysis as estimated to be 1.3×10^{-10} cm/sec (Table 3-5). This value is very low and is indicative of a very good confining unit and aquitard for groundwater within the Keokuk Formation.

Laboratory testing of unconsolidated materials identified the permeability of the undisturbed samples collected from near surface soils and loess deposits as ranging from 3×10^{-4} cm/sec to 3×10^{-7} cm/sec, and a geometric mean of 2.2×10^{-6} cm/sec. The values of the two remolded samples ranged from 2×10^{-7} cm/sec to 3×10^{-7} cm/sec, suggesting relatively low hydraulic conductivity for the unconsolidated materials.

3.5.2.4 Hydraulic Conductivity Summary

Field and laboratory tests were performed to determine hydraulic conductivity of the hydrologic units investigated at the site. Field aquifer tests included packer and slug tests, while laboratory tests consisted of flexible wall permeability tests. Geometric means of each test were calculated, as well as the geometric mean for the combined tests. The horizontal hydraulic conductivity test results are summarized below.

Formation	Packer Test Geometric Mean	Slug Test Geometric Mean	Permeability Test Geometric Mean	Combined Test Geometric Mean
Keokuk	9.7×10^{-6}	2.1×10^{-6}	not tested	4.5×10^{-6}
Warsaw	2.6×10^{-6}	not tested	not tested	2.6×10^{-6}
Salem	1.6×10^{-6}	6.9×10^{-7}	not tested	1.1×10^{-6}
St. Louis	9.6×10^{-7}	1.3×10^{-6}	not tested	1.1×10^{-6}
Unconsolidated Material	not tested	2.9×10^{-3}	2.2×10^{-6}	1.0×10^{-4}

Note: All values provided in cm/sec.

The slug test results generally confirm packer test results, and the combined results demonstrate the similarities between the tested units. It should be noted that the horizontal hydraulic conductivity of the Warsaw Shale was not measured as part of the slug test procedures. Vertical hydraulic conductivity testing of the Warsaw Shale portion of the Warsaw Formation was conducted as part of the laboratory permeability tests. As previously discussed, vertical permeability of the Warsaw Shale was found to average 1.3×10^{-10} cm/sec, indicating that the Warsaw Shale acts as an aquitard between the underlying Keokuk Formation and the overlying Salem Formation.

3.5.3 Groundwater Levels

Piezometers have been installed at the West Lake Site to monitor groundwater within the Keokuk Formation, the lower portion of the Salem Formation, and the upper portion of the Salem Formation, the St. Louis Formation, and the Missouri River floodplain alluvial deposits. A 16-month groundwater level survey was initiated in June 1995 and continued through September 1996 in order to evaluate the water level elevations in each of the geologic formations at the site and to identify the gradient and direction of groundwater flow within these formations. The water level survey consisted of measuring water levels in existing groundwater monitoring wells and in the new piezometers installed as part of the OU-2 investigation.

The water level survey was conducted by measuring water levels in selected points using an electronic water level indicator. The water level probe was decontaminated between each monitoring point with Liquinox™ and a double rinse of deionized water. Field personnel wore latex gloves when handling the water level probe. Water levels were measured from a consistent marked reference point, the north rim of the monitoring point riser pipe. Water level elevations measurements are provided in Table 3-11. The majority of the 100- and 200-series piezometers were installed and developed by June 1995. The 300-series piezometers were installed and developed by October 1995. To provide complete concurrent data sets, potentiometric surface maps from October 1995, January 1996, April 1996, May 1996, July 1996, May 2000, November 2003 and May 2004 are presented and discussed. October 1995, January 1996, April 1996, and July 1996 represent data for fall, winter, spring, and summer, respectively. May 1996 data are included because they provide additional relevant data. May 2000, November 2003, and May 2004 data are presented to provide supplemental water levels at the site. As shown in Table 3-11, alluvial water levels in May 2000 are approximately five to seven feet lower than in May 1996. The lower alluvial water levels in May 2000 are likely the result of a lower than normal precipitation during late 1999 and early 2000. Water levels in some of the St. Louis/Upper Salem and Deep Salem formation piezometers were higher in May 2000 than in May 1996, sometimes by as much as about 40 feet. Most of the higher water levels were measured in piezometers located adjacent to the active landfill. It is possible that as solid waste has been added to the landfill, the surrounding water levels have had an opportunity to return to their pre-mining elevations. As discussed elsewhere in this RI report, the active landfill has maintained an inward hydraulic gradient. The leachate recovery system in the active landfill consists of four sumps installed at the bottom of the quarry (at an elevation of approximately 240 feet MSL). In accordance with the terms of the sanitary landfill permit, the regulated leachate head is generally maintained at or below 30 feet, corresponding to an elevation of about 270 feet, MSL. Leachate pumping from the active landfill exerts hydrogeologic control on a large portion of the site by creating a hydraulic sink. Groundwater from all sides of the active landfill flow towards the risers.

3.5.3.1 Potentiometric Surfaces

Keokuk Formation

Water level elevations in the Keokuk Formation at the site range from about 439 feet MSL at PZ-111-KS to about 444 feet MSL at PZ-104-KS. These water levels are indicative of confined, artesian groundwater conditions, since the elevation of the structural surface of the Keokuk Formation is about 120 feet MSL (Figure 3-8). Water level elevations measured in October 1995, January 1996, April 1996, May 1996, and July 1996 in the KS-series piezometers were used for development of the Keokuk Formation potentiometric surface maps (*Figures 3-13, 3-14, 3-15, 3-16 and 3-17*). Water level elevations in the Keokuk Formation were also measured in May 2000, November 2003, and May 2004. These data are shown on Figures 3-18, 3-19, and 3-20.

The interpreted water level elevation in the Keokuk Formation underlying the active sanitary landfill is approximately 200 feet above the base of the active landfill and 170 feet above the regulated level in the active landfill. Based on the Keokuk Formation water level elevations and the regulated leachate levels, groundwater from the Keokuk Formation has the potential to flow upwards toward the active sanitary landfill, acting as a hydraulic barrier to potential downward flow of leachate.

Warsaw Formation

Significant groundwater was not encountered in the Warsaw Formation. Accordingly (consistent with the EPA-approved RI/FS Work Plan), piezometers were not completed within this unit, and a potentiometric surface map was not developed.

Deep Salem Formation

Four piezometers were completed in the deep portion of the Salem Formation (PZ-100-SD, PZ-104-SD, PZ-106-SD, and PZ-111-SD). Water level elevations measured in October 1995, January 1996, April 1996, May 1996, and July 1996, in the SD-series piezometers were used for development of the deep Salem hydrogeologic unit potentiometric surface maps (Figures 3-21, 3-22, 3-23, 3-24, and 3-25). Water level elevations in the deep Salem Formation were also measured in May 2000, November 2003, and May 2004. The May 2000, November 2003, and May 2004 potentiometric surface maps are shown on Figures 3-26, 3-27, and 3-28.

Water levels measured in these piezometers range between 340 and 440 feet MSL, which is 100 to 200 feet above the elevation of the base of the active landfill and 70 to 170 feet above the regulated maximum leachate level. Groundwater flow in the deep Salem Formation near the active landfill is toward the landfill. It is likely that groundwater in the Salem Formation resumes its regional northwesterly flow direction some distance west of the landfill, outside the cone of depression created by the limestone quarry excavation and the active landfill's leachate collection system.

As shown on Figure 3-24, leachate levels in LCS-1, LCS-3, and LCS-4 were abnormally high on May 3, 1996. The relatively high leachate levels were the result of temporary malfunctions of the pumps in these risers that occurred in late April. The pump malfunction coincides with approximately 5 inches of precipitation that fell between April 28 and April 30. The temporary lack of pumping in LCS-1, LCS-3, and LCS-4 allowed the leachate level in the risers to reach equilibrium with the surrounding leachate in the landfill. The temporary malfunctions were beneficial to the hydrogeologic characterization by confirming that the inward hydraulic gradient was maintained even during periods of significantly reduced leachate pumping, combined with excessive precipitation.

The leachate levels in LCS-1 and LCS-3 were also abnormally high in May 2000 as a result of temporary pump malfunctions. Leachate sump elevations are measured monthly as part of the active landfill's Permit. Between May 1996 and May 2000, the leachate sump elevations were generally maintained at or near the Permit-required levels. Similar to May 1996 data, the temporary malfunctions during May 2000 were beneficial to the hydrogeologic characterization by confirming that the inward hydraulic gradient was maintained during periods of reduced leachate pumping.

November 2003 and May 2004 water levels in the Deep Salem unit are consistent with historic data, and confirm an inward gradient toward the leachate risers.

St. Louis/Upper Salem Formations

The St. Louis Formation and the upper portion of the Salem Formation, while geologically distinct, are considered a single hydrologic unit at the site. The "SS" piezometers installed as part of the recent investigation were typically completed within the St. Louis Formation but, based on geologic conditions encountered during drilling, some of the "SS" piezometers were completed in the upper portion of the Salem Formation (i.e., PZ-106-SS, PZ-108-SS, PZ-109-SS, and PZ-113-SS). The depth of the screened intervals and the lack of a significant hydraulic flow barrier between the two formations (as indicated by the gradational contact discussed in Section 3.4.4) indicate that the formations are hydraulically connected. The formations are collectively referred to as the St. Louis/Upper Salem hydrologic unit.

Water level elevations in the St. Louis/Upper Salem hydrologic unit range from about 333 feet MSL at PZ-116-SS to about 444 feet MSL near PZ-202-SS. Water level elevations measured in October 1995, January 1996, April 1996, May 1996, and July 1996, in the SS-series piezometers were used as monitoring points for construction of the St. Louis/Upper Salem hydrologic unit potentiometric surface maps (Figures 3-29, 3-30, 3-31, 3-32, and 3-33) at the site. Water level elevations in the St. Louis/Upper Salem Formation were also measured in May 2000, November 2003, and May 2004. The May 2000, November 2003, and May 2004 potentiometric surface maps are shown on Figures 3-34, 3-35, and 3-36.

Groundwater flow near the active landfill is towards the landfill. It is likely that groundwater in the St. Louis and Upper Salem Formations resumes its regional northwesterly flow direction some distance west of the landfill, outside the cone of depression created by the limestone quarry excavation and that active landfill's leachate collection system.

The data confirm the inward hydraulic gradient east of the landfill.

Unconsolidated Materials

Groundwater is present within the unconsolidated materials in both perched and unconfined conditions. Perched groundwater is present at the contact between the loess and the uppermost bedrock (St. Louis Formation) along the eastern portion of the active sanitary landfill. No piezometers were installed to monitor the perched groundwater at the loess/limestone contact because groundwater at this contact is discontinuous and very thin (i.e., generally less than 2 feet thick).

Piezometers installed in unconsolidated materials (alluvium) as part of the recent investigation are situated in a north-south oriented line along the western edge of the active sanitary landfill, and the southern and western edges of the inactive landfill. Data obtained from these piezometers were combined with data from existing monitoring wells to develop water table maps for unconsolidated materials. Unconsolidated materials water table maps based on these data are provided in Figures 3-37, 3-38, 3-39, 3-40 and 3-41. Water level elevations in the unconsolidated materials were also measured in May 2000, November 2003, and May 2004. The May 2000, November 2003, and May 2004 potentiometric surface maps are shown on Figures 3-42, 3-43 and 3-44.

Groundwater flow within the alluvial unconsolidated materials adjacent to the active sanitary landfill is toward the landfill. An alluvial groundwater data divide apparently exists west of the active landfill, as would be expected based on regional data. East of the divide, alluvial groundwater flow is towards the active landfill. West of the divide, alluvial groundwater flow is west/northwest towards the Missouri River.

3.5.3.2 Gradient

Horizontal Gradient

Horizontal hydraulic gradients have been calculated for the Keokuk Formation and the St. Louis/Upper Salem hydrologic unit using the potentiometric contours shown in Figures 3-13 through 3-17 and 3-25 through 3-30, respectively. Gradients were calculated by dividing the difference in head between two contours by the distance between the two contours (dH/dL). The range of values was determined by interpreting these measurements at the minimum and maximum sloping areas of the potentiometric surface map.

The horizontal hydraulic gradient for groundwater flow in the Keokuk Formation was calculated to range from approximately 0.0039 feet/foot (ft/ft) to 0.0082 ft/ft. Groundwater flow within the Keokuk Formation is predominantly to the west and northwest toward the Missouri River (Figures 3-13 through 3-17). However, because the top of the Keokuk Formation is about 200 feet below the base of the Missouri River and is separated by approximately 60 feet of confining Warsaw Formation, the Keokuk Formation and the Missouri River are not expected to be hydraulically connected.

The deep Salem groundwater flow is towards the active landfill, as shown on Figures 3-21 through 3-28. The deep Salem piezometers confirm the inward hydraulic gradient to the landfill. Deep Salem piezometers were not installed to determine horizontal gradients.

The horizontal hydraulic gradient for the St. Louis/Upper Salem hydrologic unit was found to range from approximately 0.037 ft/ft to 0.008 ft/ft north of the north pit to approximately 0.45 ft/ft to 1.0 ft/ft along the west and south wall of the south pit. The gradient and direction of groundwater flow in the St. Louis/Upper Salem hydrologic unit indicate that the active sanitary landfill functions as a groundwater sink. Groundwater in the vicinity of the active sanitary landfill flows toward the landfill, with gradient increasing near the active sanitary landfill. The hydraulic head in the St. Louis/Upper Salem hydrologic units is generally about 65 to 175 feet above the leachate riser level in the active sanitary landfill.

Alluvial water levels show generally flat gradients that range below 0.0001 ft/ft. The alluvial water level in piezometers near the active landfill is about 80 to 150 feet above the leachate riser level in the landfill.

Vertical Gradient

Vertical hydraulic gradients were calculated using water level elevations measured in the piezometers at each of the four bedrock piezometer clusters. The vertical hydraulic gradient is calculated by taking the differential heads (dH) in two piezometers and dividing by the vertical distance (dL) between the screen center points of the two piezometers. The vertical hydraulic gradient is calculated to establish to vertical gradient magnitude and direction, and is a parameter used to calculate vertical groundwater velocities. Tables 3-12 through 3-16 provide a summary of the vertical hydraulic gradients calculated using water level elevations from the piezometer pairs taken on October 28, 1995, January 4, 1996, April 3, 1996, May 3, 1996, and July 12, 1996.

The bedrock vertical gradients range from –0.05 ft/ft to –0.62 ft/ft (upward) for the KS-series/SD-series piezometers and 0.03 ft/ft to 0.38 ft/ft (downward) for the SD-series/SS-series piezometers. The vertical gradient is upward from the Keokuk Formation to the Salem Formation (KS-series/SD-series). The generally strong upward gradient from the Keokuk Formation through Warsaw Shale to the Salem Formation indicates that groundwater has the potential to flow upward from the Keokuk Formation toward the base of the active landfill. In each case, the gradient is downward from the St. Louis Formation to the Salem Formation (SS-series/SD-series).

Vertical hydraulic gradients have also been calculated for piezometer clusters which include alluvium and bedrock piezometers. These gradient values are also provided in Tables 3-12 through 3-16. The vertical hydraulic gradients for the shallow alluvium to intermediate or deep alluvium and for the deep alluvium to shallow bedrock at certain piezometer clusters are generally negligible, ranging from very slightly downward to very slightly upward.

3.5.3.3 Seasonal Fluctuations

Groundwater Levels

Monthly groundwater level measurements in the newly-installed piezometers was initiated in June 1995 (Table 3-11). Piezometeric levels set in shallow bedrock wells near the active landfill reflect and are indicative of both leachate pumping and seasonal changes.

In general, water levels do not vary significantly from month to month or season to season. Water levels typically vary by one foot or so.

A significant rainfall event (2.57 inches) occurred December 18 and 19, 1995. Water levels in selected piezometers were monitored over the following 16 days. Graphs of piezometer response to the precipitation data are presented in Appendix H-2 of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2.* Monitoring yielded the following data:

- Alluvial piezometers (PZ-113-AS, PZ-113-AD, PZ-300-AS, PZ-300-AD) show little response. It is likely that the relatively high permeability of approximately 3 x 10^{-3} cm/sec in the alluvium (see Section 3.5.2) allows rapid dissipation of recharge and prevents mounding.
- In the St. Louis/Upper Salem piezometers PZ-104-SS, PZ-106-SS, and PZ-113-SS, response occurred within one to five days of the event. In St. Louis/Upper Salem piezometers PZ-100-SS, PZ-110-SS, and PZ-300-SS, little response was noted. Piezometer PZ-301-SS was not at equilibrium at the time of monitoring.
- In the deep Salem piezometers PZ-100-SD, PZ-104-SD, and PZ-106-SD, a relatively rapid response (one day) was registered. PZ-111-SD showed little response to the event.
- In the Keokuk piezometers monitored (PZ-100-KS, PZ-104-KS, PZ-106-KS, and PZ-111-KS), response to the rainfall event was slight, as expected given the presence of an overlying aquitard.

Based on the data, precipitation does not significantly affect alluvial water levels or the Keokuk potentiometric surface. Recharge does appear to affect the St. Louis potentiometric surface and the deep Salem potentiometric surface.

Daily stream flow data from the Missouri River at St. Charles were obtained from the US Geological Survey, and is correlated with observed fluctuations in piezometer well clusters PZ-100-SS/SD/KS and PZ-113-AS/AD/SS. Piezometer water levels near the active landfill are controlled by leachate pumping and any influence by river stage would be difficult to detect. The piezometers selected are of sufficient distance from the south pit to be least affected by the active landfill's inward hydraulic gradient.

Of the six piezometers selected, one is completed in shallow alluvium; one in deep alluvial materials; two within the Salem/Upper St. Louis hydrologic unit; one within the Deep Salem hydrologic unit; and one within the Keokuk Formation.

As shown in Appendix H-2 of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*, there is not a direct correlation between the Missouri River stage data and fluctuations in groundwater levels at the site. This lack of correlation is consistent with other hydrogeologic data, such as distance from the site to the riser (2 miles).

Historical stream flow data were also correlated with historical precipitation data. Stream flow data are provided in Appendix H-3 of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2.* As expected, stream flow generally increases in response to precipitation.

Gradients

Groundwater level data were used to identify variations of the seasonal gradients and direction of flow. Horizontal gradients are controlled by pumping from the landfill, so are generally unaffected by gross seasonal changes. Vertical gradients do not show significant seasonal fluctuations.

3.5.3.4 Groundwater Velocities and Flow Rates

As discussed in Section 3.5.3.2, hydraulic head data collected from piezometers screened in the Keokuk Formation, St. Louis/Upper Salem hydrologic unit, and unconsolidated materials indicate that horizontal groundwater flow in the St. Louis/Upper Salem hydrologic unit is toward the active landfill. Horizontal groundwater flow in the alluvium near the active landfill is toward the landfill. In the western portion of the site, alluvial groundwater flow is generally to the west and northwest, consistent with regional groundwater flow direction.

Typical groundwater velocities for flow within the bedrock were calculated using the horizontal gradient and hydraulic conductivity values discussed in Sections 3.5.3.2 and 3.5.2, (respectively), effective porosity values of 10 and 20 percent, and assuming steady-state conditions. Similarly, groundwater velocity was calculated for unconsolidated materials using appropriate gradient and hydraulic conductivity values, an effective porosity value of 30 percent, and assuming steady-state conditions. These porosity values are within the range presented by Freeze and Cherry (1979) for limestone, dolomite, and alluvium, and, for the bedrock units, are within the range of the two Warsaw Formation sample porosity values obtained by laboratory testing (i.e., 13.81 percent and 14.73 percent). These values should be representative of the range of effective porosity values of the hydrologic units at the site. The groundwater velocities were calculated using the following equation:

$$V = \frac{Ki}{n_e}$$

Where:

V = Average linear velocity (feet/year);
K = Hydraulic conductivity (cm/sec);
i = Hydraulic gradient (feet/foot); and,
n_e = Effective porosity.

Table 3-17 shows groundwater velocities range from 0.03 feet per year (ft/yr) to 0.2 ft/yr in the Keokuk Formation and 0.3 ft/yr to 5.0 ft/yr in the St. Louis/Upper Salem hydrologic unit. Groundwater velocity in shallow unconsolidated materials was calculated to average about 0.5 ft/yr or less, due to flat gradients.

The groundwater flow volume from the Keokuk Formation through the Warsaw Shale to the active sanitary landfill (area from which leachate is pumped) can be calculated using the following equation:

$$Q = KiA$$

Where:

Q = Groundwater flow volume (gallons/day);
K = Hydraulic conductivity (cm/sec);
i = Hydraulic gradient (feet/foot); and,

A = Approximate cross-sectional area of quarry (square feet).

Using a mean hydraulic conductivity value of 1.3×10^{-10} cm/sec, a hydraulic gradient of 1.43 ft/ft, and a unit area of about 35.9 acres (floor space of the active sanitary landfill), the groundwater flow volume theoretically entering the pit from the Warsaw Formation was calculated to be 6.2 gallons per day (gal/day). This value indicated that the volume of water entering the quarry from the lower formations is insignificant.

A vertical groundwater velocity for the Warsaw Shale has been calculated using the equation presented above. Laboratory permeability tests indicate that the mean vertical hydraulic conductivity of two Warsaw Shale core samples was 1.3×10^{-10} cm/sec. The vertical hydraulic gradient from the Keokuk Formation to the floor of the pit was calculated using the differential hydraulic head divided by the differential distance I = 442 ft – 270 ft / (240 ft – 120 ft) = 1.43 ft/ft. The average bulk porosity was calculated to be 14.3 percent. Therefore, assuming the effective porosity to be equivalent to the bulk porosity, and using parameters presented above, the vertical groundwater velocity upward through the Warsaw Formation is estimated to be about 1.4×10^{-3} ft/yr, or 3.7×10^{-6} ft/day.

3.6 Leachate Investigation

Six leachate risers designated LR-100 through LR-105 were to be drilled and installed in areas where EPA inferred that industrial and/or hazardous wastes may have been disposed (USEPA, 1989a; USEPA, 1991a). Of these six, one was dry (LR-101) and did not receive a leachate riser, while a second (LR-102) received a leachate riser but consistently exhibited a liquid thickness of less than six inches, which was insufficient for sample collection. The remaining four (LR-100, LR-103, LR-104, and LR-105) inactive landfill leachate risers were sampled to determine leachate quality.

During drilling, solid waste was identified at four of the six leachate riser borehole locations. Solid waste was not present at LR-103 and LR-104. The location of the leachate riser boreholes are shown in Figure 3-1 and the borehole logs are presented in Appendix A of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2.* At LR-100, LR-101, and LR-105, the full section of solid waste was penetrated and the base of the solid waste was identified. At LR-102, the borehole did not extend to the base of the solid waste because an apparent confining layer was identified within the solid waste. A silty layer was identified from 58.0 to 62.8 feet and separated more recent solid waste from older solid waste. The solid waste in LR-102 was saturated at a depth of 53.0 feet from the top of the landfill cap, and the silty layer also appeared to be saturated. The older solid wastes encountered below 62.8 feet were not saturated. The borehole was advanced to 76.0 feet, and the base of the borehole immediately sealed with hydrated bentonite chips below 61.6 feet to seal off the unsaturated solid wastes encountered below 62.8 feet.

In general, the solid waste consisted of common municipal wastes such as paper, plastics, clothing, construction and demolition debris. At LR-102, the older solid waste consisted of predominantly wood, construction debris, and other materials that were charred from burning.

Monitorable quantities of leachate were identified during drilling at LR-100, LR-102, and LR-105. Piezometers consisting of 2-inch ID Schedule 80 PVC were installed at these locations. At LR-101, monitorable quantities of leachate were not identified during drilling. At this borehole, old mine spoils consisting of fine sand and laminated lime deposits were encountered at 55 feet below the landfill cap. Water was encountered in the old mine spoils.

The old mine spoils were separated from the overlying solid wastes by about 3 feet of silt. Since monitorable quantities of leachate were not identified within the solid waste at LR-101, the borehole was immediately sealed with cement/bentonite grout to the surface.

At LR-103 and LR-104, solid wastes were not encountered; however, piezometers were installed in the boreholes to monitor groundwater levels in the alluvial deposits.

4.0 CHEMICAL CHARACTERIZATION

This section of the RI report summarizes the results of the various site investigation activities performed in conjunction with the development of the RI/FS for OU-2. More detailed descriptions of the RI field investigations can be found in the various reports listed in Section 1.2.3 of this document and referenced in the following discussions.

4.1 Groundwater Monitoring Network

A groundwater quality monitoring network was developed based on a detailed review of the site hydrogeologic conditions, which include:

- horizontal and vertical flow directions
- horizontal and vertical hydraulic gradients
- aquifer and aquitard permeabilities, and
- Relationship of monitoring points to potential sources of contamination.

A detailed review of the site hydrogeologic conditions was presented in the *Physical Characterization Memorandum*, dated August 1996. Four principle hydrogeologic units capable of yielding sufficient water for sampling were identified within and near OU-2. These included, from youngest to oldest, the alluvium/loess, the St. Louis/Upper Salem hydrogeologic unit, the Salem Formation, and the Keokuk Formation. The alluvium is present in the western half of the site (see Figure 2-2). On the eastern portion of the site, the uppermost water is perched within a loess deposit that overlies the St. Louis/Upper Salem hydrogeologic unit, consisting of limestone and dolomite. The St. Louis/Upper Salem hydrogeologic unit grades into the underlying Salem Formation, which is also predominantly limestone. The Warsaw Formation, a claystone and siltstone aquitard commonly referred to as the Warsaw Shale, is present between the Salem Formation and the Keokuk Formation. The Keokuk Formation was classified as predominantly limestone.

The extensive physical characterization at the site allowed development of a detailed hydrogeologic model (Figure 4-1) based on the bulleted items listed above. Leachate collection from the active landfill is the major hydrogeologic feature at the site. Leachate collection has maintained an inward hydraulic gradient from the adjacent Salem, St. Louis/Upper Salem, and alluvial hydrogeologic units that was developed when the limestone quarry created a local hydrogeologic sink by excavating below the water table. The inward hydraulic gradient prevents horizontal migration of leachate away from the landfill into the surrounding units. Vertical migration away from the active landfill is prevented by a combination of low-permeability shales that form a natural landfill liner, leachate pumping, and an upward hydraulic gradient from the underlying Keokuk Formation.

The leachate collection process has maintained a groundwater divide west of the active landfill. East of the divide, groundwater flow is toward the landfill and the leachate collection system. West of the divide, groundwater flow is relatively flat, but generally trends west/northwest toward the Earth City Stormwater Retention Pond.

4.2 Groundwater Sampling Results

The following Sections describe groundwater quality results. The Section descriptions include OU-2 sample collection procedures, background results, detection results, recent Subtitle D sampling results for the active landfill, and petroleum impacts near well MW-F2. In addition, to provide a site-wide summary of groundwater quality, a Section is included that discusses groundwater quality data for the OU-1 area.

4.2.1 Sample Collection

4.2.1.1 RI Sampling

Two groundwater sampling rounds were conducted as part of the West Lake Landfill OU-2 RI. The first sampling round began in February 1997 and extended into March 1997. The second sampling round began in May 1997 and extended into June 1997. An additional, off-schedule groundwater sampling event occurred in December 1995. The off-schedule sampling event was needed to allow collection of background quality data from piezometers PZ-300-AS, PZ-700-AD, and PZ-300-SS, plus well I-50, and S-80. Property development activities required that these locations be decommissioned early in the RI.

Groundwater sampling was conducted by first collecting water levels in the piezometers and wells. After collection of water levels, wells were purged using a Grundfos Redi-Flo II pump. Disposable polyethylene tubing was used to reduce the potential for cross-contamination. Field parameters pH, temperature, and conductivity were collected during purging. Field parameters were considered stabilized in the pH varied by less than about 0.1 pH unit, temperature varied less than approximately 1 degree Fahrenheit, and conductivity varied by less than 10% between readings. The turbidity of the water was also monitored. Purging forms are included in Appendix B of the *West Lake Landfill OU-2 RI/FS Site Characterization Summary Report*.

Purging was intended to continue until at least three casing volumes had been removed from the piezometer/well. Piezometers/Wells that purged dry with the pump were subsequently bailed dry with disposable bailers. Piezometers/Wells that purged dry were allowed to recover and were sampled. Field parameters did not always stabilize prior to sampling in wells that purged dry. Piezometers/Wells that did not purge dry were sampled using the pump after removal of three casing volumes and field parameter stabilization. Pump flow rate was maintained at approximately 200 ml/min to 600 ml/min during sampling.

Disposable polyethylene tubing was discarded after each piezometer/well was sampled. The pump was decontaminated between piezometers/well by scrubbing the electric cable and pump casing with Liquinox™ detergent, rinsing with tap water, and final rinse of laboratory-grade deionized water. In addition, the interior of the pump was decontaminated by first pumping a Liquinox™/water mixture through the pump, followed by pumping tap water, then pumping laboratory-grade deionized water. The pump was allowed to dry and was covered in plastic during transport to the next piezometer/well.

Piezometers/Wells that purged dry were allowed to recover until a sufficient volume of water had returned to the well to allow collection of at least a partial suite of compounds. In selected instances when water level recovery was extremely slow due to very formational hydraulic conductivity, it was necessary to collect a particular sample suite (e.g., semi-volatile organics), allow additional recovery, then collect another sample suite. This process was continued until all sample suites had been collected. Slow recovery piezometers/wells were sampled using disposable bailers, which were slowly lowered and raised to minimize agitation of the water. A low-flow sampling port was attached to the bailer to minimize aeration during transfer to the sample containers. New, clean rope was used in each well.

Samples were placed in laboratory supplied, pre-preserved containers. The sample containers were shipped to the appropriate laboratory under chain-of-custody. Groundwater samples collected in the February and May 1997 sampling events were analyzed for the constituents listed in Table 4-1. Groundwater samples collected in the December 1995 off-schedule sampling event were analyzed for major ions (calcium, potassium, magnesium, sodium, chloride, sulfate, bicarbonate as alkalinity), nitrate/nitrite, chemical oxygen demand, and radionuclides (gross alpha, gross beta, radium-226, radium-228, uranium-238, uranium235/236, uranium-234, thorium-232, thorium-230, and thorium-228). Off-schedule radionuclide groundwater samples were collected as both filtered (dissolved) using a 0.45 micron filter and as unfiltered (total). Metal and conventional parameters were collected as unfiltered (total).

Off-schedule groundwater samples were analyzed by Quanterra Laboratory. February and May 1997 non-radiological analyses were performed by PACE Analytical Services, Inc. Radiological analyses for the February and May 1997 groundwater samples were performed by Southwest Laboratory of Oklahoma. In addition to analyses performed by these two primary laboratories, split samples were analyzed by TriMatrix Laboratories, Inc. (non-radiological) and Paragon Analytics, Inc. (radiological). Use of primary and split laboratories provides relevant quality assurance results, as discussed in Section 5.

4.2.1.2 Supplemental Sampling

Supplemental groundwater sampling was conducted in December 2003 and May 2004 from a selected list of alluvial wells. The supplemental sampling was conducted to verify the groundwater quality results from earlier sampling events. As detailed in monthly progress reports dated March 9, 2004 and August 9, 2004, the supplemental sampling results confirmed the results from earlier sampling events.

4.2.2 Background Results

4.2.2.1 Bedrock Background Results

Background bedrock groundwater quality data are provided by piezometers PZ-300-SS, PZ-301-SS, and PZ-204A-SS. Piezometers PZ-300-SS and PZ-301-SS were installed approximately 2,000 ft south of OU-2. Piezometer PX-204A-SS was installed approximately 200 ft south of OU-2.

Tables 4-2 and 4-3 list the reported concentrations for the off-schedule background bedrock groundwater samples.

No volatile organic compounds, semi-volatile organic compounds, pesticides, and PCBs were detected in background bedrock piezometers sampled during the two scheduled sampling rounds. Selected metals were detected, as were selected radionuclides. The detected metals and radionuclides are presented in Table 4-4.

The drill water used to cool the drill bits during bedrock drilling was sampled and analyzed for a full suite of compounds, including volatile organic compounds (VOCs), semi-volatile organic compounds, pesticides, PCBs, THP, metals, and general organics. Appendix A of the *West Lake Landfill OU-2 RI/FS Site Characterization Summary Report* presents the laboratory analytical sheets for the drill water sample. Table 4-5 lists the compounds detected in the drill water sample. Chloroform was the only VOC present above the laboratory reporting limit. Chloroform was probably present as a result of municipal water treatment. No semi-volatile organic, pesticide, PCB, or TPH compounds were detected above the laboratory reporting limits.

4.2.2.2Alluvial Background Results

Background alluvial groundwater quality data are provided by wells MW-107, S-80, and I-50, plus piezometer PZ-300-AS. Wells S-80 and I-50, plus piezometer PZ-300-SS, were included in the December 1995 off-schedule sampling event. Tables 4-6 and 4-7 list the reported concentrations of the off-schedule background alluvial groundwater samples.

No volatile organic compounds, semi-volatile organic compounds, pesticides, or PCBs were detected in MW-107 in either of the two scheduled sampling rounds. Selected metals and inorganic compounds were detected, as shown in Table 4-8.

4.2.3 Detection Monitoring Results

In the following discussions, detection monitoring results are representative of groundwater sampling results from piezometers and wells installed adjacent to the OU-2 boundary. Many of the sampling points are upgradient of the site due to the inward hydraulic gradient established by the active sanitary landfill leachate collection system. Others are internal to the site and are hydraulically downgradient of selected on-site facilities yet upgradient of the active solid waste landfill. Others, particularly the alluvial piezometers and wells west of the inactive landfill, are hydraulically downgradient of the site. Detection monitoring results are considered to be all groundwater samples that were not collected from background monitoring locations described in Section 4.2.2.

4.2.3.1St. Louis/Upper Salem hydrogeologic unit

Thirteen piezometers were used to collect groundwater samples from the St. Louis/Upper Salem hydrogeologic unit near OU-2. These are listed below:

PZ-100-SS
PZ-102R-SS
PZ-1201-SS
PZ-104-SS
PZ-106-SS
PZ-110-SS
PZ-201A-SS
PZ-204-SS
PZ-206-SS
PZ-113-SS
PZ-208-SS
PZ-300-SS
PZ-301-SS

Piezometer PZ-300-SS was included in the off-schedule sampling event discussed in Section 4.2.2.

Volatile organic compounds were detected only sporadically in St. Louis/Upper Salem piezometers, and were detected at low concentrations. The detected VOCs were limited to acetone; benzene; 1,2-cis-dichloroethene; and total xylenes. Only five piezometers exhibited one or more detectable VOCs. These included PZ-102R-SS, PZ-104-SS, PZ-106-SS, PZ-1201-SS, and PZ-201A-SS. None of the VOCs was detected in both sampling rounds. All of the detections were at or near the reporting limit.

Acetone was detected in only one St. Louis/Upper Salem piezometer, and in only one of the two rounds. Acetone was detected at the laboratory reporting limit of 0.005 mg/l in PZ-1201-SS during the February sampling round, but was not detected in any St. Louis/Upper Salem piezometer during the second sampling round.

Benzene was detected at a concentration of 0.011 mg/l in PZ-1201-SS in the first sampling round compared to a reporting limit of 0.002 mg/l, but was not detected in the second sampling round. Benzene was detected in PZ-102R-SS, and PZ-106-SS during the second sampling round at low concentrations of 0.0028 mg/l and 0.0031 mg/l, respectively, but was not detected in these piezometers during the first round.

Only two additional samples exhibited an organic result above reporting limits. Cis-1,2-dichoroethene was reported at 0.0024 mg/l in PZ-110-SS during round two, but was not detected during the first sampling round. Total xylenes were detected at 0.003 mg/l, 0.002 mg/l, and 0.002 mg/l in piezometers PZ-102R-SS, PZ-104-SS, and PZ-201A-SS, respectively, during the second round, compared to a reporting limit of 0.002 mg/l. Total xylenes were not detected in the first sampling round.

No semi-volatile organic compounds were detected in the St. Louis/Upper Salem piezometers in either sampling round.

One pesticide was detected in one piezometer, in only one of the two sampling rounds. Gamma-chlordane was detected at a concentration of 0.000051 mg/l in the first sampling round compared to a reporting limit of 0.00005 mg/l. Gamma-chlordane was not detected in the second sampling round.

No PCBs were detected in either sampling round.

Table 4-9 compares the range of metal concentrations, conventional concentrations, and radionuclide activities in the St. Louis/Upper Salem piezometers to the background range. Based on the data presented in Table 4-9, many of the metals and conventionals were undetected in both the background and detection piezometers. These include beryllium, cadmium, total chromium, cobalt, dissolved copper, dissolved lead, mercury, silver, thallium, vanadium, and cyanide (total).

Six piezometers account for all of the maximum metal and conventional concentrations in the detection wells. These include PZ-1201-Ss, PZ-102R-SS, PZ-110-SS, PZ-113-SS, and PZ-201A-SS. Piezometers PZ-102R, PZ-100-SS, and PZ-201A-SS are located on the perimeter of the OU-2 area, in locations which have been shown to be consistently upgradient of OU-2. Maximum metal and conventional concentrations in these locations therefore represent naturally variability common to metal and conventional parameters. Piezometer PZ-1201-SS is located immediately adjacent to the northeastern corner of the active landfill area. PZ-1201-SS exhibited maximum concentrations of dissolved antimony nitrate/nitrite and phosphorus (total). Maximum detection values should be compared to background values to determine the potential groundwater quality differences. As shown in Table 4-9, the maximum concentrations of the parameters in PZ-1201-SS are approximately equivalent to background concentrations. Therefore, the parameters which exhibited their maximum concentrations in PZ-1201-SS represent background, unimpacted groundwater quality.

Piezometers PZ-110-SS and PZ-113-SS are located in areas internal to the site. Twenty-four of the 36 maximum metal and conventional concentrations were detected in either PZ-110-SS or PZ-113-SS. Given the presence of the inactive landfill, demolition landfill, OU-1 Area 1, OU-1 Area 2, previously-filled active landfill area, asphalt plant, and concrete plant near PZ-110-SS and PZ-113-SS, the presence of metals and conventional compounds in these two piezometers is reasonable.

Split laboratory results are consistent with the prime laboratory results. Section 5 discusses data comparability more.

4.2.3.2 Deep Salem hydrogeologic unit

Five piezometers/wells were used to monitor groundwater quality in the Deep Salem hydrogeologic unit. These include PZ-100-SD, PZ-104-CD, PZ-206-SD, PZ-111-SD, and MW-1204.

Only one VOC was detected above the reporting limit in either of the sampling rounds, and was detected in only one piezometer. Benzene was detected at a concentration of 0.013 mg/l in PZ-111-SD during the second sampling round, but was not detected in the first sampling round.

No semi-volatile organics, pesticides, or PCBs were detected in the Salem groundwater samples.

Table 4-10 compares the range of metal concentrations, conventional concentrations, and radionuclide activities in the Deep Salem piezometers to the background range for the St. Louis/Upper Salem hydrogeologic unit. No Deep Salem background piezometers were installed as parts of the OU-2 RI. Differing depositional history can often result in different metal, conventional, and radionuclide concentrations between two geologic units. Conclusions drawn based on Table 4-10 should take into account that the results are based on the two different geologic horizons.

Based on the data presented in Table 4-10, many of the metals and conventionals were undetected in the Deep Salem detection piezometers. These include antimony, beryllium, boron, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, silver, thallium, vanadium, and cyanide (total). The range of concentration for all metal and conventional parameters in the Deep Salem groundwater samples is similar to the background range, with the possible exception of barium and manganese. Similar to the results for the St. Louis/Upper Salem groundwater samples, the range of barium and manganese concentrations for the detection samples is higher than the background range. However, the range for the St. Louis/Upper Salem and Deep Salem groundwater samples are similar to each other, suggesting that the results for both the St. Louis/Upper Salem and the Deep Salem hydrogeologic unit represent natural variability.

The Deep Salem groundwater results do not suggest impacts from on-site activities. Split laboratory results are consistent with the prime laboratory results. Section 5 discusses data comparability in more detail.

4.2.3.3 Alluvium

Eleven alluvial groundwater monitoring locations were incorporated into the OU-2 RI. These include:

PZ-303-AS	MW-107
PZ-304-AS	PZ-300-AS
PZ-304-AI	PZ-300-AD
PZ-113-AS	S-80
PZ-113-AD	I-50
MW-103	

Piezometers/Wells PZ-300-AS, PZ-300-AD, S-80, I-50, and MW-107 were included in the off-schedule sampling event conducted in December 1995. These locations provide background alluvial groundwater quality data. Piezometers/Wells PZ-300-AS, PZ-300-AD, S-80, and I-50 were decommissioned prior to the two scheduled RI sampling rounds.

Only five of the alluvial monitoring locations exhibited detectable concentrations of VOCs above the reporting limit. These include PZ-113-AS, PZ-113-AD, MW-103, PZ-303-AS, PZ-304-AS, and PZ-304-AI. Piezometers PZ-303-AS, PZ-304-AS, and PZ-304-AI were installed near monitoring well MW-F2, in an area of suspected petroleum impacts, which will be discussed further Section 4.2.6. Monitoring well MW-103 is located along the western side of the inactive landfill. PZ-113-AS and PZ-113-AD are located between the inactive landfill, the demolition landfill, OU-1 Area 2, OU-1 Area 1, and the previously-filled active landfill permitted area (see Figure 1-2)

VOCs in PZ-113-AS and PZ-113-AD were limited to the chlorobenzene in PZ-113-AS and 1,1-dichloroethane in PZ-113-AD. Chlorobenzene was detected in PZ-113-AS at a concentration of 0.0086 mg/l in the first sampling round and 0.003 mg/l in the second sampling round, compared to a reporting limit of 0.002 mg/l. VOC 1,1-dichloroethane was detected at the reporting limit of 0.002 mg/l in PZ-113-AD during the second sampling round, but was not detected in the first sampling round.

The only VOC detected in MW-103 was 1,2-cis-dichloroethene, at a concentration of 0.0044 mg/l in the second sampling round. No VOCs were detected in MW-103 in the first sampling round.

VOC detections in PZ-303-AS, PZ-304-AS, and PZ-304-AI were more varied and more consistent. Table 4-11 summarizes the VOC concentration in these sampling locations.

Only one alluvial piezometer yielded a detectable concentration of semi-volatile organic compounds. PZ-303-AS exhibited detectable concentrations of four semi-volatile organic compounds in the first sampling round and three semi-volatile organic compounds in the second sampling round.

No pesticides or PCBs were detected in the alluvial wells.

Table 4-12 compares the range of metal concentration, conventional concentrations, and radionuclide activities in the alluvial piezometers to the background range. Based on the data presented in Table 4-12, many of the metals and conventionals were undetected in both the detection piezometers. These include dissolved antimony, beryllium, cadmium, dissolved chromium, cobalt, copper, lead, mercury, silver, thallium, vanadium, dissolved zinc, cyanide (total) and sulfide as S.

Five metals and conventional parameters (arsenic, barium, boron, iron, and ammonia as N) exhibit a maximum detection sample result that is about 10 times or more greater than the background maximum concentration. The maximum concentration for each of these parameter was exhibited by piezometers PZ-303-AS or PZ-304-AS, which are located along the western side of the inactive landfill. Otherwise, however, the range of detection results is similar to the range of background results, allowing for natural variability.

The organic and metal concentrations in the alluvial groundwater near OU-2 are similar to the organic and metal concentrations in OU-1 monitoring points, as described in the Groundwater Conditions Report, West Lake Landfill Areas 1 & 2, prepared by McLaren-Hart Environmental Engineering Corporation and dated November 26, 1996 and the West Lake Landfill Operable Unit 1 RI Report (EMSI, 2000a). Organic compounds were detected only sporadically, and metals were generally present at or near background concentrations.

No source of radioactivity in OU-2 has been identified or is suspected. Based on the radiological data collected as part of the OU-2 RI, groundwater quality appears to reflect natural radioactivity.

Split laboratory results are consistent with prime laboratory results. Section 5 discusses data comparability in more detail.

4.2.4 Subtitle D Sampling

Monitoring wells PZ-100-SD, PZ-100-SS, PZ-104-SD, PZ-104-SS, PZ-105-SS, PZ-106-SD, PZ-106-SS, PZ-109-SS, PZ-110-SS, PZ-111-SD, PZ-114-AS, PZ-115-AS, PZ-201A-SS, and PZ-205-SS have continued to be sampled after the two rounds of groundwater sampling conducted as part of the OU-2 remedial investigation. These wells are sampled as part of the site's environmental compliance activities under federal landfill regulations referred to as Subtitle D. The data collected as part of the OU-2 remedial investigation, plus six subsequent sampling events conducted quarterly thereafter, were used to develop a background data set from which to compare future sampling results. In the most recent sampling event, November 1999, no VOCs were detected. VOCs are considered indicators of landfill impacts to groundwater. The lack of VOCs in any of the monitoring wells confirms the inward hydraulic gradient for the active landfill.

4.2.5 Comparison of clustered piezometer groundwater quality results

Several piezometer clusters were installed as part of the OU-2 RI. These clusters provided data regarding vertical hydraulic gradients that influence groundwater flow directions, as discussed in the *Physical Characterization Memorandum*. In addition, the *Work Plan* indicated that the sampling results from the clustered locations be used to discuss vertical profiles of groundwater quality.

Piezometer clusters that have concurrent groundwater quality data include:

PZ-113AS/PZ-113-AD/PZ-113-SS
PZ-110-SS/PZ-110-SD
PZ-104-SS/PZ-104-SD
PZ-106-SS/PZ-106-SD
PZ-116-SS/MW-1204
PZ-304-AS/PZ-304-AI

Based on the general lack of detectable organic compounds throughout the site, it is not possible to utilize organic results to confidently determine vertical changes in groundwater quality. The exception is piezometer cluster PZ-304-AS/PZ-304-AI. Table 4-13 compares the detected organic compounds in PZ-304-AS to the detected organic compounds in PZ-304-AI. The few organic compounds that were detected were present at low concentrations, near the reporting limit. The cluster data support a conclusion that groundwater quality is at or near background concentrations throughout most of the site, with the possible exception of alluvial groundwater in a limited area near MW-F2 in the southwestern corner of the site.

Comparison of metal, conventional, and radionuclide results between clusters is also not useful for generating vertical groundwater quality profiles at the West Lake OU-2 site because almost all of the parameters were either undetected or were present at or near background concentrations.

4.2.6 Petroleum Impacts near MW-F2

A goal of OU-2 was to investigate potential petroleum impacts near monitoring well MW-F2 and west/southwest of the asphalt plant leaking underground storage tank site (LUST site) within the boundaries of OU-2. Based on available information, a LUST investigation at the asphalt plant began in 1993. Soil sampling conducted during removal of a 10,000 gallon underground storage tank that had been used to contain diesel fuel yielded Total Petroleum Hydrocarbon (TPH) concentrations as high as 13,270 mg/kg, with benzene, toluene, ethylbenzene, and xylenes also present. Soil concentrations were in excess of soil cleanup levels. By the end of 1993, groundwater monitoring wells had been installed in the asphalt plant area, and some of the wells exhibited floating free product on top of groundwater. Groundwater TPH concentrations were as high as 748,593 mg/l. Measured floating product thickness has exceeded 3.7 feet. Limited floating product recovery has occurred between 1993 and present. The Missouri Department of Natural Resources continued to work with the asphalt plant to develop a Work Plan for additional site characterization activities at the asphalt plant and for groundwater and soil corrective actions.

Based on groundwater elevation data discussed in Section 3, the area near monitoring well MW-F2 is hydraulically downgradient of the asphalt plant at least occasionally. Petroleum odors have historically been noted emanating from the PVC casing in MW-F2. To provide reliable groundwater quality data, piezometer PZ-303-AS was installed within about 75 ft of MW-F2 as part of the OU-2 RI. Piezometers PZ-304-AS, PZ-304-AS, and PZ-304-AI were installed about 450 ft from MW-F2.

Purgeable-range (i.e., light range) petroleum hydrocarbons and extractable-range (i.e., heavy-range) petroleum hydrocarbons were analyzed in groundwater samples. The results for PZ-303-AS, PZ-304-AS, and PZ-304-AI are summarized as follows, including supplementary sampling conducted in December 2003 and May 2004:

Sample Location	Purgeable-range hydrocarbons (mg/l)				Extractable-range hydrocarbons (mg/l)			
	Feb-97	May-97	Dec-03	May-04	Feb-97	May-97	Dec-03	May-04
PZ-303-AS	1.3	3.12	3.7	3.2	19	10	14	20
PZ-304-AS	<0.05	0.08	<0.05	<0.05	0.99	0.6	0.85	1.2
PZ-304-AI	<0.05	0.53	<0.05	<0.05	0.61	0.4	0.52	0.89

As shown there are detectable petroleum hydrocarbons in the alluvial groundwater samples collected from these locations. The highest concentrations were present in samples collected from PZ-303-AS, installed closest to MW-F2. The maximum concentration of total petroleum hydrocarbons is 20.3 mg/l (the total hydrocarbons in PZ-303-AS in February 1997.

4.2.7 Operable Unit 1 Groundwater Sampling

4.2.7.1 Non-Radiological Constituents Detected in Groundwater Samples Within and Adjacent to Radiological Areas 1 and 2

Groundwater samples were obtained from 30 wells in Operable Unit 1 for non-radiological analyses. All of the wells were completed within the alluvial aquifer. Operable Unit 1 scope of work did not include bedrock characterization. The April 2000 OU-1 RI Report (Engineering Management Support) presents the OU-1 data in detail.

Two rounds of groundwater sampling were performed for OU-1 during which non-radiological analyses were obtained. Both filtered and unfiltered samples were collected during the first round of sampling in November 1995. Only filtered samples were obtained for non-radiological analyses during the second round in February 1996.

The groundwater samples were analyzed for thirteen trace metals including: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. Eight metals were detected in both the unfiltered and filtered samples with the detected concentrations being generally similar, but slightly higher for the unfiltered samples. The five metals that were not detected in any of the groundwater samples were antimony, beryllium, cadmium, silver, and thallium. The groundwater samples were also analyzed for cyanide, but this compound was not detected in any of the groundwater samples.

Results of the groundwater analyses for trace metals are summarized on Table 4-14. The following is a narrative summary of the trace metals detected in the OU-1 groundwater samples.

- Arsenic was detected in about half the samples at concentrations ranging from 0.010 to 0.420 parts per million (ppm). Arsenic was detected at concentrations above 0.050 ppm in only four wells (S-10, S-84, MW-F3, and D-14).
- Chromium was detected in about a third of the wells at concentrations ranging from 0.010 to 0.062 ppm. Chromium was generally only detected in the unfiltered samples. It was detected in filtered samples in only two wells (S-5 and S-10) at concentrations ranging from 0.011 to 0.022 ppm.

- Copper was only detected in six wells and only in the unfiltered samples obtained from these wells. The detected concentrations range from 0.023 to 0.076 ppm.
- Lead was detected in almost all unfiltered samples at concentrations ranging from 0.0031 to 0.070 ppm. Lead was detected in only two filtered water samples (S-5 and I-4) at concentrations ranging from 0.0041 to 0.0079 ppm.
- Mercury was detected in only one unfiltered groundwater sample (D-14) at a concentration of 0.00021 ppm.
- Nickel was detected in about a third of the wells at concentrations ranging from 0.021 to 0.110 ppm. Nickel was most frequently detected in the unfiltered samples and only four wells contained nickel in both the unfiltered and filtered samples (S-5, S-82, D-12, and D-83).
- Selenium was detected in only one well (MW-101) on one occasion at a concentration of 0.038 ppm.
- Zinc: This constituent was detected in most unfiltered samples at concentrations ranging from 0.028 to 0.310 ppm. Zinc is only detected in six filtered samples (S-1, S-5, S-82, I-11, D-83, and D-93) at concentrations ranging from 0.020 to 0.077 ppm.

In addition to the limited occurrences of trace metals detected in groundwater, with the exception of arsenic, trace metals generally were only detected in the unfiltered samples of groundwater. The presence of a trace metal in an unfiltered sample can be due to either the actual presence of the trace metal in the dissolved phase and/or the presence of fine-grained soil material that is not filtered out by the well screen/sand pack. Consequently, the representativeness of trace metal occurrences in unfiltered groundwater samples is questionable. Therefore, only the areal distribution of arsenic could be examined.

The majority of the arsenic results were either non-detect or similar to the levels found in upgradient well S-80. The highest levels of arsenic were detected in the shallow well MW-F3 located near the southeast corner of Area 2 (see Figure 3-1) where in November 1995 arsenic was detected at 0.420 mg/l (ppm) in the unfiltered (total) sample fraction and 0.400 mg/l in the dissolved (filtered) fraction. None of the wells located near well MW-F3 contained elevated levels of arsenic. The second highest level of arsenic (0.049 dissolved and 0.094 mg/l total) was detected in deep well D-14 located along the southern portion of Area 1. None of the other OU-1 wells located near well D-14 displayed elevated levels of arsenic. The remaining occurrences of arsenic were either at or just slightly above background and were less than the drinking water standard of 0.050 mg/l. It should be noted that none of the groundwater samples obtained from wells located along the northern or western boundary of Area 2 contained detectable levels of arsenic. Therefore, arsenic does not appear to be migrating offsite from the West Lake Landfill. In addition, review of the arsenic occurrences in the various well clusters indicates that although arsenic may be present in the shallow alluvial groundwater, it is generally not detected in the intermediate or deeper portions of the alluvial groundwater system beneath Area 2.

Petroleum hydrocarbons in the diesel and motor oil range were detected in six wells (S-5, S-8, I-11, I-65, D-14, and D-85). The detected concentrations ranged from 0.53 to 3.5 ppm (Table 4-15). The distribution of the few monitoring wells that contained detectable levels of petroleum hydrocarbons does not indicate any discernible pattern.

Volatile organic compounds (halogenated and aromatic) were detected in about half the wells. Eleven compounds were detected in the groundwater samples (Table 4-16) including:

- Benzene was detected in three wells (I-2, I-9, and D-93) at concentrations ranging from 0.0056 to 0.011 ppm.
- Toluene was detected in one well (S-5) at concentrations of 0.019 and 0.045 ppm.
- Ethylbenzene was detected in two wells (S-5 and D-14) at concentrations ranging from 0.013 to 0.022 ppm.
- Xylenes were detected in two wells (S-5 and D-14) at concentrations ranging from 0.019 to 0.078 ppm.
- Chlorobenzene was detected in four wells (S-84, MW-F3, PZ-114-AS, and D-14) at concentrations ranging from 0.006 to 0.170 ppm.
- 1,2-Dichlorobenzene was detected in two wells (S-5 and MW-F3) at concentrations ranging from 0.0051 to 0.0081 ppm.
- 1,4-Dichlorobenzene was detected in three wells (S-5, MW-F3, and D-14) at concentrations ranging from 0.0099 to 0.050 ppm.
- Cis-1,2-Dichloroethylene was detected in three wells (S-10, S-82, and D-14) at concentrations ranging from 0.0072 to 0.034 ppm.
- 1,1-Dichloroethane was detected in one well (D-13) at concentrations ranging from 0.0076 to 0.008 ppm.
- 2-Butanone was detected in only one well (D-12) on one occasion at a concentration of 0.070 ppm.
- Acetone was detected in three wells (I-11, D-13, and D-14) during the November 1995 sampling round, but was not confirmed during the February 1996 sampling round. The detected concentrations ranged from 0.037 to 0.044 ppm.

Due to the limited number of locations containing detectable levels of volatile organic compounds, no discernible pattern could be identified. However, an upgradient potential source exists for the organic compounds detected in well PZ-114-AS. PM Resources, Inc. is located across St. Charles Rock Road to the north of West Lake Landfill and more importantly, across the street from PZ-114-AS. A document titled "RCRA Operation & Maintenance Groundwater Monitoring Field Audit Report" compiled by the Missouri Department of Natural Resources (MDNR), Air and Land Protection Division, Environmental Services Program and submitted on March 12, 2003 to the MDNR-Air and Land Protection Division-Hazardous Waste Program provides relevant details. According to the March 12, 2003 document, the Environmental Services Program performed a field audit at the PM Resources site in support of MDNR's agreement with the U.S. Environmental Protection Agency to conduct Groundwater Compliance Monitoring Program inspections at Resource Conservation and Recovery Act facilities in Missouri. According to the Report mentioned above, PM Resources is a facility that produces a wide variety of animal health care products including pharmaceuticals, medical feeds, rodenticides, sanitizers, cleaners, and pesticide products. The facility has been producing these types of products since 1970. The 2003 report states that a catchment system was utilized as part of the production process. The 2003 report does not discuss specific details regarding the catchment system. The 2003 report states that in September 1994 the owner removed the catchment system. Upon removal of the system, it was revealed that a release of hazardous chemicals had occurred.

The chemicals released from the catchment system included petroleum products such as benzene, toluene, ethylbenzene, and xylenes (BTEX) along with some of their volatile breakdown components. Contaminants of concern at the PM Resources, Inc. site are BTEX and volatile by-products involved with the removal of the catchment system and pesticides and herbicides that may have been released during the facility's production history. As described in a May 2005 report titled "Selection of Chemicals of Concern in Groundwater, PM Resources, Inc.", volatile organic chemicals of concern in groundwater at the PM Resources facility include the following, along with their maximum detected concentrations:

- 1,2,3-trimethylbenzene (60.4 ug/l)
- 1,2,4-trimethylbenzene (370 ug/l)
- 1,3,5-trimethylbenzene (3.7 ug/l)
- acetone (4,000 ug/l)
- benzene (13 ug/l)
- carbon disulfide (489 ug/l)
- chlorobenzene (11,000 ug/l)
- ethylbenzene (560 ug/l)
- methyl tert-butyl ether (5,650 ug/l)
- nitrobenzene (25 ug/l)
- tetrahydrofuran (3,750 ug/l)

The following table summarizes the VOC detections at PZ-114-AS:

Summary of VOC Detections at PZ-114-AS			
Sampling Date	**Benzene (ug/L)**	**Chlorobenzene (ug/L)**	**1,4-Dichlorobenzene (ug/L)**
8/25/1997	<5	7	<5
11/10/1997	<5	5.1	<5
2/16/1998	<5	<5	<5
5/27/1998	<5	<5	<5
11/12/1998	<5	7.2	<5
5/19/1999	<5	<5	<5
11/19/1999	<5	<5	<5
5/23/2000	<5	<5	<5
11/13/2000	<5	<5	<5
5/15/2001	<5	7.7	<5
11/7/2001	<5	5	<5
5/21/2002	<5	130	<5
7/24/2002*	NA	150	NA
11/19/2002	<5	120	5.5
5/28/2003	<5	110	6.2
11/20/2003	6.1	120	14
5/11/2004	5.4	130	18
11/17/2004	<5	96	11
5/25/2005	<5	102	12.2

**Denotes Confirmation Sampling Event.*

Methane gas was monitored in the headspace of PZ-114-AS and adjacent deeper well PZ-115-SS during the November 2003 and May 2004 routine groundwater compliance monitoring events for the Bridgeton Landfill. Methane was detected in PZ-114-AS during the November 2003 sampling event, but methane was non-detect in the PZ-114-AS headspace during the May 2004 sampling event.

A map showing the location of the PM Resources facility in relationship to the Bridgeton Landfill is included as Figure 4-2. Figure 4-2 also includes potentiometric surface contours using water level data collected in wells at the PM Resources facility and the Bridgeton Landfill. As shown on Figure 4-2, groundwater flows from the PM Resources facility toward the Bridgeton Landfill and the PZ-114-AS location.

Given that benzene and chlorobenzene were detected in groundwater at both the PM Resources facility and PZ-114-AS, with concentrations much higher at the PM Resources facility than at PZ-114-AS, the PM Resources facility appears to be the source of benzene and chlorobenzene detected at PZ-114-AS. The identified direction of groundwater flow from the PM Resources facility toward the Bridgeton Landfill and PZ-114-AS provides support for this conclusion.

1,4-dichlorobenzene has been detected sporadically at PZ-114-AS, but is not detected in groundwater at the PM Resources facility. 1,4-dichlorobenzene is a daughter product of 1,2,3-trichlorobenzene and 1,2,4-trichlorobenzene, neither of which has been detected at the PM Resources facility. 1,4-dichlorobenzene is also a daughter product of 1,2,3,4-tetrachlorobenzene, which has not been analyzed at the PM Resources facility. It appears that 1,4-dichlorobenzene at PZ-114-AS could be related to the PM Resources facility or to landfill gas. It should be noted that the Maximum Contaminant Level for 1,4-dichlorobenzene (AKA paradichlorobenzene or p-dichlorobenzene) is 75 ug/l, and the maximum detected concentration in PZ-114-AS is 18 ug/l. The maximum detected concentration of 1,4-dichlorobenzene in PZ-114-AS is therefore about 4 times lower than the MCL.

Semi-volatile organic compounds (Table 4-17) were detected in six OU-1 wells (MW-F3, I-11, I-62, D-3, D-12, and D-14). The compounds detected were 1,4-dichlorobenzene, 4-methylphenol, di-n-octyl phthalate, and bis(2-ethylhexyl)phthalate, and the detected concentrations ranged from 0.012 to 0.290 ppm. The only compound detected during both sampling rounds was 1,4-dichlorobenzene (0.018 and 0.038 ppm) in D-14. The compound 1,4-dichlorobenzene was also detected using USEPA Method 8240 for VOCs. The compound 1,4-dichlorobenzene was also detected in the two samples from this well by the SVOC analytical method (USEPA Method 8270). Concentrations detected by the SVOC analytical method were equal to or less than the concentrations reported by the VOC (USEPA Method 8240) analytical method. Due to the extraction procedure in the semi-volatile organic compound analysis, it is possible that some of the 1,4-dichlorobenzene was lost; therefore, the results of the VOC analytical method may be more reliable.

Three pesticides were detected during the November 1995 OU-1 sampling round but not confirmed during the February 1996 sampling. The three pesticides detected were 4,4-DDD, aldrin, and lindane. The detected concentrations ranged from 0.000011 to 0.00011 ppm (Table 4-18). No PCB aroclors were detected in any of the OU-1 groundwater samples.

4.2.7.2 Radionuclide Levels in Groundwater: Operable Unit 1

Four groundwater sampling events occurred as part of radionuclide characterization of groundwater quality for Operable Unit 1. The November 1995 and February 1996 events correspond to non-radiological sampling events described in Section 4.2.7.1 A third sampling event was conducted in May of 1996 to provide supplemental thorium-230 and radium-226 data. A fourth radionuclide sampling event was conducted in May 1997 to provide supplemental radiological data for a few Operable Unit 1 wells. Supplemental sampling was conducted in 2004 in conjunction with the FS. The results of the RI and the supplemental groundwater sampling indicated that radium is present in two OU-1 wells, D-3 and D-6 at levels slightly greater than the MCL of 5 pCi/l for the total of Radium-226 and -228 isotopes.

Constituents in the uranium-238, uranium-235, and thorium-232 decay series were detected in both of the upgradient background wells (S-80 and MW-107). Constituents in the uranium-238, uranium-235, and thorium-232 decay series were measured near background levels in the non-background OU-1 landfill wells. Constituent levels were generally below 3 pCi/l in the landfill wells. In addition, there were minimal differences between the results obtained from the filtered and unfiltered samples.

Missouri MCLs apply to combined analysis of radium-226 plus radium-228 and/or gross alpha radioactivity. The groundwater samples collected in May 1997 were the only samples analyzed for gross alpha, radium-226, and radium-228. The analytical results indicate that only the sample from well D-6 exceeded the State MCLs. The value measured at D-6 was very close to the MCL (a combined radium-226 and radium-228 value of 5.98 pCi/l verses the MCL value of 5.0 pCi/l). The unfiltered result of 1.88 pCi/l reported by McLaren-Hart (1996b) for the 1996 sampling. The filtered results obtained from this well during these two sampling events were also quite close, 1.66 pCi/l in May 1997 compared to 2.03 pCi/l in May of 1996.

Well D-6 is part of a three well cluster located in the buffer zone on the Ford property at the toe of the landfill berm along the northern boundary of Area 2. The other two wells in this cluster are wells S-61 and MW-102. The levels of radium-226 found in well S-61 are similar to those found in background well MW-107 and less than levels found in background well S-80. Radium-228 was note detected in well S-61; however, the MDA levels were quite high for these analyses. Well MW-102 was not sampled as part of the OU-1 RI effort (Dame & Moore, 1991). This well was sampled prior to the OU-1 RI effort. Results of the analysis of the unfiltered sample from this well found radium-226 at 1.1 pCi/l and did not detect radium-228 at a detection limit of 1.4 pCi/l. Neither radium isotope was detected in the filtered sample from this well. Based on the results of these and other groundwater analyses, Dames & Moore (1991) concluded "....only four (4) of sixteen (16) samples showed detectable Ra-226 concentrations, all of which were within normal background levels of 1 pCi/l (1.1 to 1.6)." Based on both the OU-1 RI and the Dames & Moore results, it does not appear that the source of the radium occurrences in well D-6 is the result of vertical migration from overlying soils or shallower groundwater.

Well D-3 is located in western portion of Area 1. Radium was not detected in well D-3 at levels above the MCL during sampling performed for the RI; however, it was detected above the MCL during sampling performed in March and May of 2004 in conjunction with the FS. As radium was neither detected at levels above or even close to the MCL in wells S-5 and I-4 completed at shallower depths at the same location as D-3 nor in any other wells in and around Area 1, the cause of the more recent reported occurrences of radium in well D-3 could not be identified.

The S-10, I-11, and D-12 well cluster is located approximately 500 feet to the southeast, and approximately upgradient from the D-6 well cluster. The S-10 well cluster is located within the boundaries of Area 2. Review of the analytical results obtained from these three wells indicates that the radium-226 levels in the groundwater upgradient of the D-6 well cluster are less than 1 pCi/l, similar to, or less than the levels found in the upgradient, background wells. The radium-228 results from these wells are generally non-detect; however, the MDA levels were high. The only exception is the May 1997 radium-228 results obtained from deep well D-12 which indicate that the radium-228 level ranged from 0.47 to 0.67 pCi/l, again within the expected background levels. Based on the lack of elevated radium levels in any of the wells located immediately upgradient of well D-6, it does not appear that the source of the radium levels detected in well D-6 is from upgradient groundwater.

Based upon the available data, the source of the radium levels found in well D-6 cannot be ascertained. It is possible that the radium concentration detected in this well could be the result of either vertical migration from the overlying radiologically impacted materials or from lateral migration from upgradient areas. However, the available data do not support either of these mechanisms as the source of the radium levels in well D-6. One possible source of the radium levels in well D-6 is cross-contamination during drilling activities. It is possible that some of the surficial soil containing radionuclides that are present on the Ford property in the vicinity of well D-6 were knocked into or otherwise released into the boring during the drilling or construction of well D-6. If this did occur, the introduced soil could act as a source of the observed groundwater occurrences of radium in this well.

Although elevated levels of radionuclides and non-radionuclides have been detected in various wells completed within or adjacent to OU-1 portions of the landfill, a plume or contiguous area of radionuclide or non-radionuclide constituent occurrences in groundwater at concentrations above regulatory standards or risk-based levels is not present at the West Lake landfill. This conclusion is consistent with previous conclusions made by Radiation Management Corporation (RMC) as part of their investigation of the radiological materials at the West Lake Landfill (RMC, 1982). RMC concluded, "These results indicate that the buried ore residues are probably not soluble and are not moving off-site via ground water."

4.3 Surface Water and Sediment Sampling Results

4.3.1 Surface Water

Staff gauges were monitored monthly coincident with water level measurement. The measurements were initiated in June 1995. The monthly survey was conducted by visually measuring the surface water elevation along the incremented staff gauge.
Surface water samples were analyzed for the same compounds as groundwater. As shown in Appendix C of the *West Lake Landfill OU-2 RI/FS Site Characterization Summary Report*, all volatile organic, semi-volatile organic, pesticide, and PCB results were below detection in both the upstream sample and in the sample collected west of the inactive landfill. With regard to inorganic parameters, the upstream and downstream surface waters exhibit similar concentrations. The radiological results are also consistent between the upstream and downstream. The upstream sample exhibited low levels of uranium-234 and uranium-238 while the downstream sample did not yield detectable levels of these isotopes. These results illustrate the natural variability of radioactivity in the area, and substantiate the fact that the OU-2 area is not contributing radionuclides to surface water.

In summary, based on the surface water results, the OU-2 area is not contributing measurable contamination to the Earth City Stormwater Retention Pond.

4.3.2 Sediment

Sediment samples were collected adjacent to the corresponding surface water sample locations, to allow direct comparison of surface water and sediment quality at the designated locations.

Sediment samples were analyzed for the same list of compounds as groundwater and surface water, except that all metals were analyzed as total, conventionals included only total cyanide and sulfide, and radionuclides were not analyzed. Consistent with the EPA-approved Work Plan, the sediment analyte list included VOCs, semi-volatile organics, pesticides, PCBs, petroleum hydrocarbons, total cyanide, sulfide, and metals.

Based on the sediment results, the OU-2 area is not contributing measurable contamination to the Earth City Stormwater Retention Pond.

4.4 Soil Sampling Results

The surface and subsurface soil investigation activities were completed to characterize the distribution and extent of hazardous constituents within the landfill mass.

The samples were collected in brass liners inside a California Barrel sampler. Headspace analysis of the individual soil sample from the soil borings was conducted to determine if volatile organic compounds were present. The individual soil samples from two foot intervals were immediately place in jars and sealed. After the borehole was completed and soil samples had warmed up to ambient air temperature, the air headspace over the soil samples in the jars was screened with a MiniRae photoionization detector for volatile organic compounds. The headspace readings were recorded on the soil borehole logs (Appendix A of the *Physical Characterization Technical Memorandum for West Lake Landfill OU-2*). The results of the headspace analysis were used to select a soil sample from each of the soils boring to submit for analytical laboratory analyses. If elevated readings were not detected, the soil sample collected nearest the water table was submitted for laboratory analysis.

The selected soil samples were delivered to Quanterra Incorporated under strict Chain-of-Custody procedures. The samples were immediately placed on ice and shipped overnight to the laboratory in sealed coolers.

Alluvial soil samples from the screened interval in the "300"series piezometers and leachate risers LR-103 and LR-104 were analyzed for total organic carbon (TOC). Soil samples from PZ-303-AS were analyzed for total petroleum hydrocarbons (TPH) and VOCs due to the piezometer's proximity to monitoring well MW-F2. Soil samples were collected during drilling of four soil borings near monitoring well MW-F2 (Figure 3-1) were analyzed for TPH and VOCs. The TPH and VOC results can be used to determine potential impacts from the landfill gas and groundwater migration.

Table 4-19 lists the TOC results from the piezometers, leachate risers, and soil gas boreholes drilled outside the inactive landfill footprint. Alluvium was not encountered in PZ-300-SS; therefore TOC analyses were not performed on this piezometer. Leachate risers LR-103 and LR-104 encountered alluvial soils during drilling, and were therefore included in the TOC analyses. Soil gas borehole alluvial samples were collected at a depth of approximately 3.5 ft below ground surface.

Based on the TOC results presented in Table 4-19, TOC values near the ground surface west of the inactive landfill range from 2,300 mg/kg (0.23%) to 10,000 mg/kg (1%). These results may be biased high because of potential landfill gas migration through the near-surface soils adjacent to the inactive landfill, which would have allowed transfer of organic compounds from the gas phase to the soils. Based on the piezometer TOC results, background TOC in the alluvium at depth is approximately 240 to 480 mg/kg (0.024% to 0.048%).

Two TOC values from the piezometer and leachate riser borehole soil samples were elevated. The TOC value obtained in PZ-300-AS at a depth of 16 to 16.5 ft below ground surface was 4,600 mg/kg (0.46%). Piezometer PZ-300-AS was a background piezometer installed approximately 2,000 ft south of the West Lake Landfill, in an apparently naturally wooded area. It is possible that the alluvial soils in this area are naturally higher in TOC than in any other areas investigated as part of the OU-2 RI. Leachate riser LR-103 yielded a TOC value of 20,000 mg/kg (2%) from a depth of 32.5 to 33 ft below ground surface. Leachate riser LR-103 was drilled through a solid waste fill associated with the inactive landfill before encountering alluvium at depth.

Because elevated organic concentrations were suspected in piezometer PZ-303-AS, and because PZ-303-AS was drilled the closest of any piezometer to the MW-F2 area west of the asphalt plant LUST site, TPH and VOC analyses were substituted for TOC analysis. Table 4-20 lists the TPH and VOC results for the two alluvial soil samples collected from PZ-303-AS, as well as soil borings drilled specifically to identify the extent of potential petroleum impacts near MW-F2. Detectable VOCs were limited to toluene, ethylbenzene, and total xylenes (common petroleum constituents) in the PZ-303-AS samples and SB-01, drilled adjacent to MW-F2. TPH results were presented as purgeable (i.e., lighter fraction) and extractable (i.e., heavier fraction). In the PZ-303-AS sample collected from a depth of 17 ft below ground surface and the SB-01 sample, the extractable fraction was present at a higher concentration than was the purgeable fraction. This suggests that petroleum impacts near the ground surface adjacent to the MW-F2 area are associated with the diesel range of compounds. Extractable-range petroleum hydrocarbons were detected in three of the four soil boring samples. Purgeable-range petroleum hydrocarbons and VOCs above the laboratory reporting limit, were present only in SB-01, nearest to the MW-F2 area.

The TPH and VOC results support the potential for petroleum impact in a limited area near MW-F2, west/southwest of the asphalt plant LUST site.

4.5 Leachate Sampling Results

Leachate sampling and analysis were conducted to determine whether past disposal practices might have resulted in source areas for contamination in the inactive landfill. Specifically, the EPA, in the *Aerial Photographic Analysis of the West Lake Landfill Site, Bridgeton, Missouri* (EPA, 1989a and 1991a), identified standing water pools that were inferred to represent potential liquid disposal areas (Figure 1-6) within the inactive landfill. The leachate sampling points were installed in areas identified by the EPA as potential liquid disposal areas. The data obtained from the leachate risers were intended to be used to identify potential hazardous substances, if present, within these areas of the inactive landfill.

In addition to sampling leachate from the inactive landfill, samples of leachate were collected from leachate risers (LCS-1 through LCS-4) previously installed within the active sanitary landfill. The leachate riser data from the active sanitary landfill can be compared to the leachate quality in the inactive landfill.

The *Work Plan* indicated that leachate samples would be analyzed for the same list of compounds as groundwater and surface water samples. Leachate samples were analyzed for VOCs, semi-volatile organics, pesticides, PCBs, petroleum hydrocarbons, total cyanide, sulfide, metals, and radionuclides. Although selected conventional parameters included in groundwater and surface water samples were inadvertently deleted from the leachate analyte list, the VOC, semi-volatile organic, pesticide, PCB, petroleum hydrocarbon, total cyanide, sulfide, metals, and radionuclide data are sufficient to characterize leachate quality and meet the objectives of the RI.

Table 4-21 compares organic compounds above laboratory reporting limit for the leachate risers in the active sanitary landfill (labeled with a prefix "LCS") to organic compounds above laboratory reporting limit for the leachate risers in the inactive landfill (labeled with a prefix "LR"). Organic compound detection frequency was low in each group of leachate risers. Only one organic compound (total petroleum hydrocarbons) was detected in two of the four inactive landfill leachate samples (LR-103 and LR-104). All other organic compounds were below detection in these two samples. Organic compound concentrations for detected compounds in the inactive landfill leachate are consistently within the range of the concentrations for the active sanitary landfill leachate. Solvents, such as tetrachloroethene, trichloroethene, vinyl chloride, etc., were not detected in the inactive landfill leachate samples.

Radionuclide concentrations in the inactive landfill leachate samples were similar to the radionuclide concentrations in the active sanitary landfill leachate (see Appendix C of the *West Lake Landfill OU-2 RI/FS Site Characterization Summary Report*). The active sanitary landfill is not permitted to accept radioactive waste. Based on the similar radionuclide concentrations, a significant source of radioactivity is not present in the inactive landfill.

In summary, fewer organic compounds were present in the inactive landfill leachate and were detected at lower concentrations than in the active sanitary landfill leachate. In addition, no solvents were present in the inactive landfill leachate. These results indicate that standing water pools identified by EPA in its aerial reconnaissance review were most likely not liquid disposal locations. Rather, the standing water pools were most likely the results of small depressions that collected precipitation.

4.6 Landfill Gas Sampling Results

Landfill gas characterization was accomplished using various measurement techniques. Health and safety air monitoring was conducted during the drilling of each of the 49 boring completed as part of the OU-2 RI to determine potential landfill gas impacts in the breathing zone. Health and safety air monitoring equipment included a photoionization detector and a combustible gas indicator, which were used to verify that methane, hydrogen sulfide, and organic compound concentrations remained at or near background levels. Health and safety air monitoring results were consistently within acceptable background ranges throughout the OU-2 RI, indicating that appreciable landfill gas impacts were not occurring. Hydrogen cyanide was to be quantified during the OU-2 RI only if gas was observed actively venting from the boreholes. Active venting was not observed, and hydrogen cyanide measurements were made infrequently at the beginning of the OU-2 RI field program to confirm the lack of impacts. Hydrogen cyanide was not detected.

Additional landfill gas monitoring was conducted along the western portion of the inactive landfill. An ATV mounted geoprobe drill rig advanced expendable sampling points to a depth of approximately 3.5 ft below ground surface at 10 locations shown in Figure ~~4-2~~ 4-3. The holes were observed for natural venting. If natural venting of landfill gas was observed, the holes were allowed to vent for approximately 20 minutes before sampling. If natural venting was not observed, a peristaltic pump was attached and the hole was purged for 20 minutes to draw landfill gas into the hole. Polyethylene tubing was connected to the sampling point and a new Tedlar bag was used at each sampling point. The Tedlar bag was placed inside a vacuum box, and a vacuum was applied, causing landfill gas to be drawn into the Tedlar bag. The Tedlar bag assured consistent volumes of landfill gas at each sampling point. After the sample container was filled, a photoionization detector and combustible gas indicator were used to determine volatile organic compound, hydrogen sulfide, and combustible gas emissions in the sample bag.

Results of the soil gas are presented in Table 4-22. Hydrogen sulfide was not detected in any of the 10 locations. The percent lower explosive limit was zero in eight of the 10 locations. SG-03 exhibited a landfill gas concentration at 3% of the lower explosive limit at a depth of 3.5 ft below ground surface. Location SG-08, near monitoring well MW-F2, exhibited a landfill gas concentration of 130% of the lower explosive limit at a depth of 3.5 ft below ground surface. Locations SG-03 and SG-05 were the only two to exhibit detectable concentrations of organic vapors. Sample SG-03 exhibited an organic vapor concentration of 7.6 ppm. Sample SG-05 exhibited an organic vapor concentration of 10.1 ppm. These landfill gas results indicate sporadic, isolated landfill gas impacts near the inactive landfill, and are typical for solid waste landfill.

Direct measurements of landfill gas were made by collecting gas in SUMMA canisters from 10 boreholes drilled within the inactive landfill. The boreholes were installed along the crest of the inactive landfill (Figure 4-2), in areas where the landfill gas would likely accumulate and as companion measurement points for selected leachate risers discussed in Section 3.3.2. An ATV mounted Geoprobe drill rig advanced expendable sampling points to a depth of approximately 3.5 ft below ground surface. The holes were observed for natural venting. If natural venting of landfill gas was observed, the holes were allowed to vent for approximately 20 minutes before sampling. If natural venting was not observed, a peristaltic pump was attached and the hole was purged for 20 minutes to draw landfill gas into the hole. Polyethylene tubing attached to the expendable sampling point was connected at ground surface to a SUMMA canister. SUMMA canisters were used to directly collect samples of landfill gas for subsequent laboratory analysis of organic compounds using EPA Method TO-14 by Air Toxics, LTD. of Folsom, California. Detected compounds included Freon compounds, which are commonly associated with refrigerants that were probably disposed as "white goods" (i.e., refrigerators, etc.) within the active landfill. White goods were historically not separated from other solid waster material and would be expected in an older solid waste landfill such as the inactive landfill.

Table 4-23 compares landfill gas constituents presented in *Integrated Solid Waste Management Engineering Principles and Management Issues* (Tchobanoglous, et al, 1993) to the inactive landfill gas constituents. For compounds present on both the inactive landfill gas and typical landfill gas, the concentrations of inactive landfill compounds are less than the mean results for typical landfill gas compounds, with the exception of acetone. The acetone concentration for the inactive landfill gas, although slightly greater than the mean concentration in typical landfill gas, is still an order of magnitude less than the maximum concentration for typical landfill gas.

Selected compounds were present in the inactive landfill gas that were not reported in typical landfill gas and may not have been part of the Tchobanoglous, et al study (Table 4-23). These were present at low concentrations and do not suggest a definable source of hazardous substances that is emitting significant vapors into the inactive landfill gas.

An additional landfill gas sample was collected from the headspace in monitoring well PZ-1201-SS. The headspace sample was collected to determine if landfill gas has the potential to impact groundwater quality adjacent to the landfill areas. The headspace sample was collected by imitating a groundwater sampling event, which involved purging the well to dryness using a purge/sampling pump. The piezometer was capped with a specially–designed cap fitted with an in-line vapor sampling port to allow direct collection of gas. After allowing time for the water level in the piezometer to recover, a SUMMA canister was attached to the sampling port. A stopcock was opened, and the SUMMA canister collected a representative sample of vapors from within the piezometer. The SUMMA canister was shipped to Air Toxics, LTD. for analysis or organic vapors using EPA Method TO-14. The headspace sample yielded detectable concentrations of chloromethane, methylene chloride, benzene, ethyl benzene, xylene, acetone, carbon disulfide, and methyl ethyl ketone (2-butanone). As discussed in Section 4.2.3, groundwater in piezometer PZ-1201-SS exhibited detectable concentrations of acetone and benzene. These results suggest that landfill gas at the site has the potential to impact groundwater and can be considered the source of low-levels of organic compounds in groundwater.

In summary extensive health and safety air monitoring data indicate that landfill gases are not significantly impacting air quality. Landfill gas is present within the inactive landfill, as with all landfills, but for the most part is present at lower concentrations than at typical solid waste facilities. Landfill gas data do not support the presence of widespread or concentrated liquid disposal within the active landfill area. A similar conclusion was reached for the inactive landfill area based on leachate sampling results discussed in Section 4.5. Based on gas monitoring conducted immediately west of the inactive landfill and in the headspace of piezometer PZ-1201-SS, landfill gas is migrating into the surrounding geologic media, and has the potential to impact groundwater quality adjacent to the active sanitary landfill and inactive sanitary landfills. A landfill gas monitoring system has recently been installed near the active sanitary landfill and will provide supplemental landfill gas data to determine compliance with solid waste landfill regulations.

4.7 Seep Investigation

The entire OU-2 area was repeatedly observed for the presence of landfill seeps. No seeps capable of exiting the site were found. One seep was initially observed in the northeastern portion of the inactive landfill, near the asphalt plant. Any flow from this seep would remain in the area immediately surrounding the seep, and would have no possibility of off-site impact. The seep was observed to flow only minimally. A sample was collected and was submitted for analysis. The laboratory experienced severe analytical problems to the extent that additional samples were required. Despite repeated walk-overs of the seep area, no additional seepage was observed. This suggests that the seep was a temporary feature and was not a significant component of the overall RI/FS.

5.0 QUALITY ASSURANCE SAMPLES AND DATA VALIDATION

Data validation of environmental samples collected as part of the West Landfill OU-2 RI was performed. The purpose of the data validation was to assess the precision, accuracy, representativeness, completeness, comparability, and sensitivity of the analytical data reported and compare these attributes to the project goals set in the *Work Plan*, Appendix A-2, Final Quality Assurance Project Plan (QAAP) (Golder, 1995b).

Quality assurance (QA) goals were evaluated by reviewing the results of both field and laboratory QA samples. Field QA samples collected included field duplicates, field blanks, equipment rinseate blanks, and trip blanks. Field QA samples were collected at the frequency specified in the Work Plan. In addition to the collection of field QA samples, selected samples were split and sent to both primary and split laboratories. Some split sample locations proposed in the *Physical Characterization Memorandum* were modified in an attempt to select samples with detectable concentrations of target analytes. Agreement of the results between the two laboratories provides one method to assess the comparability of the data sets.

Laboratory QA samples analyzed included calibration standards, method blanks, laboratory control samples, matrix spike/matrix spike duplicate samples, and laboratory duplicate samples.

5.1 Analytical methods

Table 5-1 summarizes the groundwater, surface water, leachate, sediment, soil, and air samples that were collected for the West Lake OU-2 RI. Off-schedule groundwater samples collected in December 1995 were analyzed by Quanterra Laboratory of North Canton, Ohio. These samples were found to be 100% complete. Soil samples collected during drilling of piezometers, monitoring wells, and leachate sumps in 1995 and a sample of the water used for drilling were also analyzed by Quanterra and validated.

Groundwater, surface water, leachate, sediment, soil, and air samples were collected during the first sampling round in February and March of 1997. The second round of sampling, conducted in May and June of 1997, included only groundwater samples. One air sample was collected in October 1997. Selected groundwater, surface water, leachate, and sediment samples were split and sent to both a primary and split laboratory for analysis. The primary non-radiological laboratory was Pace Analytical Services, Inc., Houston, Texas. Analyses for Method 8310 PAHs were conducted at Pace's Petaluma, California laboratory. The primary radiological laboratory was Southwest Laboratory of Oklahoma, Broken Arrow, Oklahoma. The split non-radiological laboratory was TriMatrix Laboratories, Inc., Grand Rapids, Michigan and the split radiological laboratory was Paragon Analytics, Inc., Fort Collins, Colorado. Soil samples were analyzed at PACE, Houston and air samples were analyzed by Air Toxics, LTD., Folsom, California.

Off-schedule 1995 groundwater samples were analyzed for major ions (calcium, potassium, magnesium, sodium, chloride, sulfate, and bicarbonate), nitrate/nitrite, chemical oxygen demand (COD), and radionuclides (gross alpha, gross beta, radium-226, radium-228, uranium-234, uranium-235/236, uranium-238, thorium-228, thorium-230, and thorium-232). Soil samples collected during drilling in 1995 and the drill water sample were analyzed for parameters appropriate for the location sampled. Five samples from PZ-303-AS, SB-01, and SB-02 were analyzed for volatiles by EPA Method 8260, purgeable and extractable hydrocarbons by Method 8015M, and percent moisture by Method 160.3M. Nine samples from PZ-300-AD, PZ-300-AS, PZ-302-AS, PZ-302-AI, PZ-304-AS, PZ-304-AI, PZ-305-AI, LR-103, and LR-104 were analyzed for Total Organic Carbon (TOC) by the Walkley-Black Method (Standard Methods of Chemical Analysis, 6th edition, 1963) and percent moisture. Three samples from SB-03 and SB-04 were analyzed for purgeable and extractable hydrocarbons by Method 8015M, and percent moisture by Method160.3M. The drilling water sample was analyzed for volatiles by Method 8260, semi-volatiles by Method 8270A, pesticides and PCBs by Method 8080, purgeable and extractable hydrocarbons by Method 8015M, metals by the 6000 series Methods, mercury by Method 7470, inorganics (ammonia, chloride, fluoride, hardness, nitrate/nitrite, total phosphorus, sulfate, sulfide, TOC, total cyanide, COD, and total dissolved solids) by the 100-400 series Methods, and radionuclides (gross alpha, gross beta, radium-226, radium-228, uranium-234, uranium-235/236, uranium-238, thorium-228, thorium-230, and thorium-232) by the 900 series Methods.

Groundwater, surface water, leachate, and sediment samples collected in 1997 were sent to PACE Analytical Services and analyzed for RCRA Subtitle D appendix I volatiles by EPA SW-846 Method 8260A; CLP target compound list semi-volatiles by Method 8270, pesticides and poly-chlorinate biphenyl (PCBs) by Method 8081; RCRA Subtitle D appendix I list total metals plus total boron, calcium, iron, magnesium, manganese, mercury, and sodium by the 6010/7000 series Methods; total cyanide by Method 9010; sulfide by Method 9030; and total petroleum hydrocarbons (diesel and gasoline ranges) by Method8015M. Groundwater and surface water samples were also analyzed for 1,2-dibromomethane and 1,2,3-trichloropropane by Method 8011; bis (2-chloroethyl) ether, 2-nitoraniline, nitrobenzene, n-nitrosodi-n-propylamine, and pentachlorophenol by Method 8000M; benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene by Method 8310; hexachlorobenzene and hexachlorocyclopentadiene by Method 8081; RCRA Subtitle D appendix I list dissolved metals plus dissolved boron, calcium, iron, magnesium, manganese, mercury, and sodium by the 6010/7000 series Methods; total organic carbon (TOC) by Method 415.1; chemical oxygen demand (COD) by Method 410.4; and common anions and water quality parameters (ammonia, chloride, fluoride, hardness, nitrate/nitrite, phosphorus, sulfate, and total dissolved solids) by the 100-300 series Methods. Soil samples from borings made to collect air samples were analyzed by PACE, Houston for TOC by Method 12-90-3 (Methods of Soil Analysis, American Society or Agronomy, 2nd edition, 1982).

PACE Analytical Services analyzed 48 groundwater samples, eight leachate samples, two surface water samples, two sediment samples, and 10 soil samples. Additional analyses were performed on field duplicates, field blanks, equipment blanks, and matrix spike/matrix spike duplicate samples as listed in Table 5-1.

Eight groundwater (six primary and 2 field duplicate), one surface water, one sediment, two leachate, and additional QA samples were split and sent to TriMatrix Laboratories for analysis of the same parameters by the same methods listed above.

Southwest Laboratory of Oklahoma (SWLO) analyzed 48 groundwater, eight leachate, two surface water, and additional QA samples for total and dissolved gross alpha and gross beta by Method 900M; total and dissolved isotopic thorium (Th-230) and uranium (U-234, U-235, and U-238) by Methods 907M and 908M; and total and dissolved radium-226 by Method 903M.

Six groundwater, one surface water, and two leachate samples were split and sent to Paragon Analytics for analysis of the same radiological parameters by the same methods as SWLO, with the exception of radium, which was reported as total radium (radium-226 and radium-228). Total radium was not reported for the three groundwater samples collected during the second sampling round because the high solids content of the samples prevented the accurate determination of chemical recoveries.

Ten air samples and one field duplicate were analyzed by Air Toxics, LTD. for volatile gases by EPA Method TO-14.

5.2 Data Validation procedures

Groundwater, surface water, sediment, and leachate sample results for 1997 were reported in Contract Laboratory Program format data packages. The analytical results were validated using laboratory acceptance criteria and the procedures and guidelines contained in the following documents: National Functional Guidelines for Inorganic Data Review, revised February 1994; National Functional Guidelines for Organic Data Review, revised February 1994; and Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), Third Edition, November 1996 and revisions.

Items checked for inorganic data packages (if provided) included holding times, initial and continuing calibration results, method and field blank results, ICP interference check sample results, laboratory control sample (LCS) recoveries, spike sample (MS/MSD) recoveries, field duplicate results, compound quantitation, and transcriptions from raw data to the summary forms.

Organic data packages were checked for holding times, instrument performance check, initial and continuing calibration results, method and field blank results, surrogate or system monitoring compound recoveries, matrix spike/matrix spike duplicate and LCS recoveries, internal standard recoveries, field duplicate results, target compound identification, compound quantitation, and transcriptions from raw data to the summary forms.

QA items and raw data missing from the original data packages were requested from the applicable laboratory and added to the data package. Sample results were qualified as estimated detected "J". estimated non-detected "UJ", not detected "U", or unusable "R", based on the guidelines reference above. The qualifiers have been added to the database and are now a permanent part of the analytical result. The original validated packages have been retained in the project files.

5.3 Precision, accuracy, representativeness, completeness, comparability, and sensitivity

Validation results were reviewed to evaluate the precision, accuracy, representativeness, completeness, comparability, and sensitivity of the analyses.

Precision is a measure of the reproducibility of sample results. It is assessed by tabulating the results of the relative percent difference (RPDs) of matrix spike/matrix spike duplicate (MS/MSD) and laboratory control sample/laboratory control sample duplicate (LCS/LCSD) analyses. RPDs that fall within the QA control limits indicate acceptable precision. The precision numbers reported below indicate the percentage of RPDs for these analyses that fall within the control limits.

Accuracy is the degree of agreement between the measured value and an accepted reference or true value. Accuracy was assessed by evaluation of the percent recoveries for the MS/MSD analyses, laboratory control samples (LCS), surrogates or system monitoring compounds (SMC), and method or preparation blank results. The reported accuracy indicates the percentage of recoveries and blank results within the laboratory or method control limits.

Representativeness is the degree to which the data accurately and precisely represent the concentration of target analytes in the samples. Representativeness was assessed by evaluating the RPDs between field duplicate results. The reported representativeness indicates the percentage of RPDs that are within the validation control limits of 20% for aqueous samples (groundwater, surface water, and leachate) and 35% for sediment samples.

Completeness indicates the percentage of valid sample results (results not rejected) obtained from the validation procedures versus the total number of sample results. It was calculated as the number of acceptable results divided by the total number of results.

Comparability expresses the confidence with which one data set can be compared to another. Qualitatively, different data sets can be considered to be comparable if the samples were analyzed following the same analytical methods and validated by the same procedures. The reported comparability indicates the percentage of split sample RPDs that are within the validation control limits set of 20% for aqueous samples (groundwater, surface water, and leachate) and 35% for sediment samples.

Sensitivity is the measure of the attainment of the health-based contract-required method detection limits (CRDLs). It was calculated as the number of sample results with detection limits that meet the CRDLs divided by the total number of sample results for analytes that have CRDLs specified.

5.3.1 Precision

The overall project precision, based on the percentage of MS/MSD and LCS/LCSD RPD results within the control limits, was 95.6%. Precision of data was 94.1% for PACE Analytical Services, 97.1% for TriMatrix Laboratories, and 100% for Quanterra Laboratory. Precision can not be calculated for the radiological analyses because the laboratories do not use RPD results as acceptance criteria for duplicate analyses and the analyses do not take estimated error into account. Precision can not be calculated for the air results because no duplicate spike analyses were performed.

5.3.2 Accuracy

The overall accuracy, based on the percentage of MS/MSD, LCS, surrogate or system monitoring compound, and method or preparation blank within control limits, was 97.6%. Accuracy of data for each laboratory was 96.8% for PACE Analytical Services, 98.9% for TriMatrix Laboratories, 94.3% for Southwest Laboratory of Oklahoma (SWLO), 87.9% for Paragon Analytics, 99.5% for Quanterra Laboratory, and 99.0% for Air Toxics. Samples for the total radium analyses conducted by Paragon Analytics during the first sampling round were inadvertently filtered, and therefore, these sample results should be considered biased low.

5.3.3 Representativeness

The overall project representativeness, based on the percentage of field duplicate RPDs within the validation control limits, was 99.5%. Representativeness for each laboratory was 96.8% for PACE Analytical Services, 99.0% for TriMatrix Laboratories, 57.1% for Southwest Laboratory of Oklahoma, 59.3% for Paragon Analytics, and 100% for Air Toxics. Representativeness by media was 95.7% for groundwater, 96.2% for surface water, 88.8% for sediments, 99.4% for leachates, and 100% for air. The low representativeness of the radionuclide results from Southwest Laboratory of Oklahoma and Paragon Analytics is a function of the very low activities present at the site. Results were near the minimum detectable activities, which caused variability between the original sample and the field duplicate sample result.

5.3.4 Completeness

The overall project completeness, defined as the percentage of data not rejected, was 97.1%. Completeness for each laboratory was 96.9% for PACE Analytical Services, 96.6% for TriMatrix Laboratories, 100% for both Southwest Laboratory of Oklahoma and Paragon Analytics, 99.8% for Quanterra, and 95.7% for Air Toxics. Paragon Analytics achieved 100% completeness for the first sampling round despite inadvertently filtering total radium samples because these results were not rejected. Rather, the filtered radium results are considered to be acceptable as supplemental dissolved radium values.

Completeness by media was 96.6% for groundwater samples, 97.6% for surface water samples, 99.4% for sediment samples, 98.0% for leachate samples, 100% for soil samples, and 95.7% for air samples. The completeness goals for each of these media, as specified in the QAAP, are 95% for groundwater, 80% for surface water, 80% for sediments, 95% for subsurface soil samples, and 95% for landfill gas (air) samples. A completeness goal for the leachate samples was not specified.

5.3.5 Comparability

The overall project comparability, based on the percentage of split sample RPDs within the validation control limits, was 89.1%. Comparability by media as 89.6% for groundwater sample pair, 88.2% for surface water sample pairs, 95.8% for sediment sample pairs, and 84.1% for leachate sample pairs.

Comparability of the non-radiological analyses was 92.9% overall and 90.3% for groundwater, 91.4% for surface water, 95.8% for sediments, and 87.6% for leachates. For the radiological analyses, comparability was 31.6% overall and 36.9% for groundwater, 21.4% for surface water, and 12.5% for leachates. Radiological analyses were not performed on the sediment samples. The low comparability of the radionuclide results is a function of the very low activities present at the site. Results were near the minimum detectable activities, which caused variability between laboratories.

5.3.6 Sensitivity

The overall project sensitivity, based on the number of sample results that met the health-based contract-required method detection limits, was 99.5%. For non-radiological analyses, the sensitivity for PACE Analytical Services was 100%, and the sensitivity of TriMatrix Laboratories was 98.9%. For the radiological analyses, the sensitivity was 93.7% for Southwest Laboratory of Oklahoma and 100% for Paragon Analytics.

Sensitivity by media was 99.5% for groundwater samples, 99.9% for surface water samples, and 100% for sediment samples. Health-based detection limits were not established for the leachate, soil, or air samples.

5.4 Resampling of PZ-303-AS

To provide the best possible suite of data from which to characterize OU-2 site conditions, a third groundwater sample was collected from PZ-303-AS. This additional sample was collected in March 1997, and was analyzed for pesticides/PCBs. The additional sampling was undertaken because of discrepancies in PCB results for PZ-303-AS between the primary laboratory and split laboratory based on the February 1997 samples. The split laboratory detected two PCBs in the February 1997 sample collected from PZ-303-AS. The split laboratory detected Arochlor-1248 and Arochlor-1260 in the February 1997 sample, at concentrations of 0.025 mg/l and 0.0087 mg/l respectively. The primary laboratory did not detect any PCBs in February 1997 PZ-303-AS sample, at a reporting limit of 0.0005 mg/l. The March 1997 resample included both filtered (dissolved) and unfiltered (total) pesticide/PCB analyses. The split laboratory did not detect any pesticides/PCBs in the filtered (dissolved) resample, but detected Arochlor-1248 at a concentration of 0.0012 mg/l in the unfiltered (total) sample. Consistent with the February 1997 sample, the primary laboratory did not detect any pesticides or PCBs in the resamples, either as filtered or unfiltered. The primary laboratory maintained a PCB reporting limit of 0.0005 mg/l for the resamples, which is lower than the reported Arochlor-1248 concentration from the split laboratory.

5.5 Quality Assurance Summary

The data quality objectives for the OU-2 RI were met by generating defensible, reliable data that can confidently be used to assess the risks posed by the site. All project goals for data completeness were met.

6.0 BASELINE RISK ASSESSMENT (BRA)

A baseline risk assessment was prepared by Veritox, Inc. and is being submitted concurrently with the RI Report. The BRA provides an assessment of baseline risks and environmental impacts. It is one of the key elements in the process to evaluate hazardous waste sites as set forth under the Comprehensive Environmental Response, Compensation Liability Act (CERCLA). The following sections summarize the BRA.

The United States EPA has recognized that certain categories of sites – for example, municipal landfills – have similar characteristics, such as types of contamination, types of disposal practices, or how environmental media are affected (USEPA, 1993b). Based on information acquired from evaluating and cleaning up these sites, USEPA has initiated the use of presumptive remedies to accelerate cleanup at these sites. The USEPA has determined that the presumptive remedy guidance for municipal landfills applied to this site (Administrative Order on Consent, Docket No. 111-94-F-0025, Section 22). As part of the presumptive remedy approach, the BRA may be streamlined to facilitate action to address obvious threats to human health or the environment.

6.1 Human Health Evaluation

This section presents the streamlined human health risk assessment for West Lake Landfill OU-2. Section 6.1.1 provides an exposure assessment that includes a conceptual model, identification of key exposure media, exposure pathways and receptors, and a comparison of site contaminant levels to potential chemical-specific ARARs (Applicable or Relevant and Appropriate Requirements) as recommended in the streamlined approach. The toxicity assessment presents a brief discussion of toxicity information for contaminants that were detected and exceed the potential chemical-specific ARARs. A risk characterization is also presented that addresses the significant results of the streamlined risk assessment.

6.1.1 Exposure assessment

The exposure assessment for the BRA for OU-2 was developed consistent with the presumptive remedy approach for evaluating municipal landfills. This included development of a conceptual model to better understand the site dynamics as to sources of contaminants of potential concern (COPCs), contaminant release, and transport and potential human environmental receptors.

As recommended by USEPA guidance, the evaluation of exposures was also streamlined by comparing RI-derived contaminant concentrations to potential chemical ARARs instead of presenting a quantitative assessment of exposure.

6.1.1.1 Conceptual Model for OU-2

A conceptual model for OU-2 has been developed as part of the baseline risk assessment. The conceptual model has been based on the conceptual model presented in the OU-1 Baseline Risk Assessment (Auxier, 1998) and the generic conceptual model presented by USEPA for municipal landfill sites. The purpose of the conceptual site model is to describe the site and its environs and to present potential sources and types of contaminants, transport and release mechanisms, potential affected media, possible exposure mechanisms and potential human and environmental receptors. The conceptual model illustrated in Figure 6-1 facilitates evaluation of the risks to human health by providing a basis for identifying and evaluating potential risks to human health from the contaminants detected in OU-2 media. It is based on the following assumptions:

- The property is currently partially covered with vegetation. The vegetative cover can become more sparse or more dense as time progresses and is dependent on future land uses.
- The infiltration rate of water through the West Lake Landfill soils does not change.
- Surface water runoff is currently collected and channeled by the existing ponds and ditches.
- The future source term is unaffected by chemical degradation.
- The reasonable future use of the Site is commercial-industrial, not residential. In addition, deed restrictions have been recorded against the entire West Lake Landfill.

A source of COPCs, a release mechanism, an exposure route, and a receptor are all necessary components of a complete exposure pathway. If any one of these elements is missing, the exposure pathway is incomplete and no exposure can occur.

The text that follows provides the rational for focusing the streamlined analysis on the specific receptors, exposure routes and contaminant sources that provide the greatest potential contributions to human health risk.

6.1.1.2 Sources of Contamination

Municipal, industrial, and commercial wastes from the OU-2 landfill area are considered potential sources of contamination for the risk assessment. Contaminants from these sources can contribute to exposures for current and potential future receptors. Sources and pathways to key receptors are presented in the OU-2 conceptual model (see Figure 6-1).

6.1.1.3 Potential Release/Transport Mechanisms and Media

Chemicals may be released into the environment by a number of processes. These processes are referred to as “release/transport mechanisms” in the conceptual model and this report.

Release/transport mechanisms at the West Lake Landfill were identified by recognizing the potential interactions of the physical environment with the sources in the OU-2 landfill. The release mechanisms evaluated for OU-2 sources are discussed in the following paragraphs.

1) Direct Contact

Chemicals in surface soil particles can come into direct contact with an individual either through direct dermal contact or ingestion.

2) Volatilization/Wind Dispersion

Volatile chemicals can escape directly from a solid matrix as a vapor in a process called volatilization. Chemicals released in this manner mix with adjacent air and can move freely with the wind. Surface soil particles containing contaminants can also be picked up by winds passing over areas of exposed soil and become suspended for a time in air. This release mechanism has been included in this assessment because the vegetative cover at the West Lake Landfill may decrease in the future, resulting in an increased potential for releases.

3) Soil Erosion and Runoff

Chemicals in surface soils can be picked up and carried by flowing surface water during runoff events.

4) Leaching/Infiltration/Percolation

Soluble chemicals within a soil matrix can be dissolved by water percolating through the soil. These dissolved chemicals can then pass through the soil and enter the groundwater beneath the West Lake Landfill. The degree to which a chemical dissolves in water or remains sorbed to the soil matrix is described by the distribution coefficient, K_d, for the element of chemical. A distribution coefficient describes the partitioning of a chemical to soil and to water as the concentration in soil is divided by the concentration in water. The higher the numerical value of the distribution coefficient of a chemical in soil matrix, the less soluble it is.

5) Radon Emission

Radon is an inert gas that is generated by the decay of radium. Because it is a gas, radon produced in a soil matrix can potentially escape from the soil into the air above it. This is a common process that occurs in all soils, because all soils contain some radium. This release mechanism only becomes significant when radium concentrations in soil reach a critical level. This critical level depends on many factors including the type of soil, the grain size, and the presence of overlying soil. Radon emission has been included as a release mechanism in this risk assessment because of radiologically contaminated soils in the adjacent OU-1. Radon can migrate through the soil and waste matrices and could theoretically move to OU-2. Based on the data collected, however, this transport mechanism does not appear significant for exposures at OU-2.

6) Landfill Gas

Several gases are typically generated by decomposition of organic materials in a landfill. The principle gases are carbon dioxide, methane, nitrogen, and hydrogen sulfide. Other toxic volatile compounds may also be present. Migration of landfill gas can pose an on-site and off-site fire and explosion hazard. Landfill gas can volatilize and mix with adjacent air. Health and safety air monitoring results were consistently within acceptable background ranges during the site characterization. This indicates that landfill gases are not significantly impacting air quality (Water Management Consultants, 1997). Landfill gas can also become soluble in groundwater.

6.1.1.4 Exposure Mechanisms

A receptor can come into contact with contaminants in media in a variety of ways, generally as a result of a receptor's work activities, behavior or lifestyle that brings him/her into contact with a contaminated exposure medium. This assessment describes the exposure routes that bring a receptor into contact with a potentially contaminated medium.

An exposure route describes how a chemical may enter or affect the human body through inhalation, ingestion, and absorption across dermal surfaces.

The remainder of this section describes the exposure routes evaluated in the BRA. The potential receptors evaluated for these exposure routes are described in Section 6.1.1.5 below.

1) Exposure from Air

This route assumes a receptor inhales air that contains suspended particulates and gas originating in soil or waste.

2) Exposures from Direct Contact with Soil or Surface Water

Receptors may come into contact with contaminated soil or surface water. During the period of contact, the receptors may be exposed through dermal contact with these contaminated media or via inadvertent ingestion of a small amount of soil or surface.

3) Exposures from Proximal Exposure

Receptors who work near radiologically contaminated areas may be exposed via external exposure. That is, high-energy particles from radionuclides can have harmful effects without being taken into or brought in direct contact with the body. OU-2 does not include radiologically contaminated soils. Therefore, this potential route of exposure is not considered to be part of a complete pathway.

4) Exposure from Ingestion

Receptors may ingest contaminated groundwater through the use of residential and/or commercial wells or, as indicated above, though inadvertent ingestion of a small amount of contaminated soil or surface water.

6.1.1.5 Potential Human Receptors

Information about the current operation practices at the West Lake Landfill and both current and expected future land-use around the West Lake Landfill was used to identify potential receptors that could be impacted by contaminants found in OU-2 media. Although the process for the streamlined BRA did not quantitatively evaluate all potential receptors, it is important to identify receptors and scenarios that combine reasonable land-use assumptions with the greatest potential for exposure at the West Lake Landfill. The OU-1 BRA (Auxier, 1998) provided extensive discussion on several generic receptor scenarios that were considered to be compatible with current and expected future land use of the West Lake Landfill property and surrounding area.

Potential receptors for OU-2 were determined from the OU-1 BRA and by considering compatibility with current and expected future land use and access controls on the West Lake Landfill and adjacent properties. The landfill is surrounded by industrial/commercial property. Casual access to the landfill is currently restricted with fences, signs, and periodic visual inspection. In addition, restrictive covenants prohibit groundwater wells, residential use, and construction of buildings at the West Lake Landfill. Likely human receptors are presented in the conceptual model (Figure 6-1) and include the following.

1) Current Scenarios for Receptors within OU-2 Boundaries

Current plausible receptor scenarios for the OU-2 area of the West Lake Landfill are limited to on-site workers such as groundskeepers and transients/trespassers.

2) Current Receptor Scenarios on Property Surrounding the West Lake Landfill

Potential receptor scenarios were compared to existing land use practices and access controls on property near the landfill. The landfill is surrounded by industrial/commercial property. Casual access to the area is possible, but no permanent residences are located within approximately one-fourth mile of OU-2. Plausible receptor scenarios for these locations include trespassers and industrial/commercial workers. There is also the potential that affected groundwater could be used by residential or commercial receptors located off-site of the landfill.

3) Future Receptor Scenarios

Current land-use practices in the properties around the West Lake Landfill and restrictive covenants on the West Lake Landfill were used to forecast the future land-use practices on these properties. The reasonable future use of the Site is commercial-industrial, not residential. In addition, deed restrictions have been recorded against the entire West Lake Landfill. Residential land use and groundwater wells have been precluded on the West Lake Landfill by restrictive covenants, which can be changed only with the consent of MDNR, EPA, and the landowner. These land use and restrictive covenants limit the number of future plausible receptor scenarios on OU-2 to trespassers or on-site workers such as a groundskeeper. As under current conditions, there is potential for groundwater and contaminants from OU-2 to move off-site where it could be used by residential or commercial receptors located off-site of the landfill.

The receptor scenarios judged to be compatible with current and future uses of the West Lake Landfill were then evaluated to determine if a plausible means of exposure existed; i.e., whether contaminants detected in OU-2 media reach receptors.

4) Current Receptor Scenarios

The on-site worker scenario and the trespasser scenario for the West Lake Landfill have complete exposure pathways for contact with surface soil, surface water/sediment, leachate, soil gas, and air. The only exposure route possible for a building user on the West Lake Landfill is inhalation of resuspended dust or radon. This route has been eliminated from further consideration as a current exposure scenario based on negative results of air monitoring data and indoor radon measurement data collected by the landfill operator (McLaren-Hart, 1996b, Golder, 1996; as cited by Appendix A, BRA West Lake Landfill OU-1, Auxier, 1998). Therefore, an on-site building user does not have any complete exposure pathways.

Receptors at commercial/industrial sites surrounding the West Lake Landfill could potentially be exposed from inhalation of landfill gas releases to ambient air through use of groundwater impacted by OU-2.

5) Future Receptor Scenarios

Land use and covenant restrictions limit the number of future plausible receptor scenarios on OU-2 to trespassers or on-site workers such as groundskeeper. The on-site worker scenario and the trespasser scenario for the West Lake Landfill have complete exposure pathways for contact with surface soil, surface water/sediment, leachate, soil gas, and air. As under current conditions, there is potential for groundwater with contaminants from OU-2 to move off-site where it could be used by future residential or commercial receptors located off-site of the landfill. Thus, there is a potential exposure through the ingestion, inhalation, and dermal pathways for contaminants in groundwater.

6.1.1.6 Identification of Contaminants of Concern

The streamlined approach to evaluating risks at CERCLA municipal landfill sites differs from the typical baseline risk assessment in that quantitative calculations of intakes and risks are not conducted. Instead, pathways that are an obvious threat to human health and the environment are identified by comparing site-specific contaminant concentrations to standards or risk-based chemical concentrations (USEPA, 1991b). Standards and risk-based chemical concentrations have both been used in this streamlined BRA for OU-2 as discussed below.

As indicated by USEPA, standards that are potential chemical-specific ARARs are maximum contaminant levels for drinking water supply systems (MCLs) and non-zero maximum contaminants level goals (MCLGs) as presented in 40 CFR 141. National Primary Drinking Water Regulations (NPDWRs or primary standards) are legally enforceable standards that apply to public water systems. Primary standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are know or anticipated to occur in public water systems. The MCL, as the Safe Drinking Water Act defines, is the level protective of human health that may be achieved with the use of the best available technology, treatment techniques, and cost taken into consideration. Secondary MCLs are also available that provide reasonable goals for drinking water quality. They generally address parameters that affect taste, odor, or the aesthetic quality of drinking water or impacts to the drinking water system such as corrosivity.

Risk-based chemical concentrations are chemical-specific and media-specific concentrations that are developed using standard default exposure assumptions, USEPA toxicity data and target cancer risks, or target hazard quotients. Essentially, risk-based concentrations are risk assessments in reverse, where a concentration is calculated based on a target risk value, as opposed to calculating a risk value given to a know constituent concentration. The risk-based concentrations used in the streamlined BRA for OU-2 are the USEPA Region 9 Preliminary Remediation Goals (PRGs). PRGs are risk-based tools for evaluating and cleaning up contamination sites. They are being used to streamline and standardize all stages of the risk evaluation process at contaminated sites.

The Region 9 PRGs combine current EPA toxicity values with "standard" exposure factors to estimate contaminant concentrations in environmental media (soil, air, and water) that are considered protective of human, including sensitive groups, over a lifetime. Chemical concentrations above these levels would not automatically designate a site as "dirty" or trigger a response action. However, exceeding a PRG suggests that further evaluation of the potential risks that may be posed by site contaminants may be appropriate.

PRGs are chemical concentrations that correspond to fixed levels of risk (i.e. either a one-in-one-million (10^{-6}) cancer risk or a noncarcinogenic hazard quotient of 1in soil, air, and water. In most cases, where a substance causes both cancer and noncancer (systematic) effects, the 10^{-6} cancer risk will result in a more stringent criteria.

The following sections provide the comparison of site contaminant concentrations to MCLs, MCLGs, or PRGs on a medium-specific basis. Only groundwater has both potential chemical-specific standards (i.e., MCLs or MCLGs) and PRGs. Only PRGs are available to evaluate the other media. Maximum concentrations of detected contaminants in a medium are compared to the MCL, non-zero MCLG, or PRG. This is a conservative evaluation to identify potential impacts to human health because the maximum concentration is not present at all sample locations. For the OU-2 BRA, (and consistent with the streamlined approach recommended by USEPA (USEPA, 1991b)) if the site-specific contaminant concentration exceeds a standard (i.e., MCL or non-zero MCLG), it is considered a Contaminant of Concern for the risk assessment. If no standard exists, then the site-specific contaminant concentration is compared to a PRG based on maximum beneficial use, that is residential use, of the medium. Contaminants that exceed a PRG but do not exceed an existing standard are not considered Contaminants of Concern.

Identification of Groundwater Contaminants of Concern

Table 6-1 details all Contaminants of Concern (COCs) for each hydrogeologic unit sampled as part of the West Lake Landfill OU-2 Site Characterization. Iron, manganese, and total dissolved solids exceed MCLs or non-zero MCLGs in all hydrogeologic units.

The alluvial hydrogeologic unit contained a larger number of COCs when compared to the other hydrogeologic units, which is expected given its closer proximity to the inactive landfill contents. Detected parameters that exceeded MCLs or non-zero MCLGs for the alluvial hydrogeologic unit included arsenic, iron, manganese, chloride, total dissolved solids, total petroleum hydrocarbons, benzene, bis (2-ethylhexl)phthalate and vinyl chloride. Bis (2-ethylhexl)phthalate was only detected one time in all of the sampling events (frequency of detection 1/19, see Table 6-2). Therefore, although it exceeds an MCL, its presence has not been confirmed. The St. Louis/Upper Salem hydrogeologic unit parameters that exceeded MCLs or non-zero MCLGs included iron, manganese, fluoride, total dissolved solids, and benzene. Benzene was only detected in 3 out of 24 St. Louis/Upper Salem groundwater samples (Table 6-3), and was not detected in any one piezometer in both sampling rounds. Therefore, its presence has not been confirmed. Finally, detected parameters that exceeded MCLs or non-zero MCLGs for the Deep Salem hydrogeologic unit included iron, manganese, and total dissolved solids. Benzene was detected once (frequency of detection 1/11) in this aquifer at a concentration exceeding the MCL. Therefore, its presence is not confirmed.

The majority of the inorganic and conventional parameters that exceeded MCLs or non-zero MCLGs in the sampled hydrogeologic units can be explained by variations in background. However, organic COCs in the alluvial hydrogeologic unit exceed MCLs and MCLGs by such a factor as to warrant consideration of remedial action under the presumptive remedy approach. In addition, the majority of the parameters that exceeded the MCLs and/or MCLGs were located within the inactive landfill in the immediate vicinity of MW-F2.

Identification of Soil Contaminants of Concern

Soil data collected, as part of the West Lake Landfill Characterization did not have any parameters that exceeded recommended PRGs. Therefore, there were no contaminants of concern identified for this medium.

Identification of Leachate Contaminants of Concern

Leachate sampling for the West Lake Landfill as part of the Site Characterization identified a number of detected parameters as presented in Table 4-21. There are not standards for leachate constituents. Leachate will not be used as a drinking water source so comparison to

PRGs based on drinking water is not appropriate. However, a comparison of parameters detected in leachate to COCs in groundwater is useful to identify leachate parameters that could potentially impact drinking water. Table 6-5 provides a comparison of detected leachate parameters to groundwater COCs. Two parameters, arsenic and benzene, found in leachate are also present as COCs in groundwater.

The leachate from the inactive landfill has fewer detected parameters and at lower concentrations than the active landfill. This is probably due to its greater age. Also, the USEPA concern that liquid hazardous waste disposal occurred in the inactive landfill is not supported by the results of the leachate sampling.

Identification of Soil Gas Contaminants of Concern

Several contaminants were detected during landfill gas monitoring for the OU-2 Site Characterization as shown in Table 6-6. The West Lake Landfill gas constituents and concentrations are typical of municipal solid waste landfill gas as discussed in Section 8 of the Site Characterization Report (Water Management Consultants, 1997).

Table 4-23 compares typical concentrations of landfill gas constituents to the detected levels of inactive landfill gas constituents in OU-2. For compounds present in both the inactive landfill gas and typical landfill gas, the concentrations of inactive compounds are less than the mean result for typical landfill gas compounds, with the exception of acetone. The acetone concentration for the inactive landfill gas, although slightly greater than the mean concentration in typical landfill gas, is still an order of magnitude less than the maximum concentration for typical landfill gas.

Photoionization detectors as well as combustible gas detectors were used for health and safety air monitoring during site characterization to verify that methane, hydrogen sulfide, and organic compound concentrations remained at or near background levels in ambient air. These results were consistently within acceptable background ranges throughout the OU-2 RI, indicating that appreciable landfill gas impacts were not occurring to the ambient air. Detection sampling conducted within the inactive landfill indicated sporadic, isolated landfill gas impacts that are typical for a solid waste landfill.

There were other compounds detected in the landfill gas that were not reported in typical landfill gas. However, these compounds were present at low concentrations and do not suggest a definable source of hazardous substances that is emitting significant vapors into the inactive landfill gas.

PRGs are not used to evaluate landfill gas for this streamlined BRA. PRGS are based on ambient air exposures and represent levels that correspond to a risk of daily lifetime exposures. It is not likely that any individual will be exposed to these parameters identified in the landfill gas under conditions on which the PRGs are based. Exposures will likely occur for short periods of time during routine maintenance and/or landfill gas monitoring activities. Given these factors, landfill gas is not an exposure concern at the detected levels.

6.1.1.7 Uncertainty Associated with the Exposure Assessment

With the streamlined approach to risk assessment there are a number of uncertainties and assumptions in the exposure assessment. Examples of such include assumptions that the groundwater will leave the landfill and remain at the same concentrations and that the detected parameters will reach receptors at the concentrations identified in the Site Characterization. In addition, the maximum concentrations rather than the average concentrations are used in determining whether or not parameters exceed standards and the standards assume lifetime exposure to the COCs, which are not likely to occur in this scenario. These assumptions have the effect of overstating the risk.

Another assumption in this approach is that the land use will remain the same in the future. For the West Lake Landfill OU-2 area it is highly likely that land use will remain the same for this area.

6.1.2 Toxicity Assessment

The general procedures for conducting a toxicity assessment are presented in Section 7 of RAGS, Part A (USEPA, 1989b). The toxicity assessment for the baseline risk assessment identifies chemical-specific toxicity factors and briefly discusses the key toxicities associated with chemicals evaluated in the BRA.

The streamlined approach to the OU-2 BRA utilized the toxicity information in a manner different from the typical quantitative risk assessment. Chemical-specific toxicity factors are not used to calculate contaminant specific-risks. Instead, they are used as part of the calculation of the PRG in order to derive risk-based contaminant concentrations that can be compared to site contaminant concentrations.

The following sections briefly discuss the toxicity factors used in the streamlined BRA for OU-2.

6.1.2.1 Toxicity Assessment for Noncarcinogenic Effects

System, toxic effects (other than cancer) may be associated with exposures to chemicals. The toxicity value used to evaluate potential noncancer (i.e., noncarcinogenic) effects is the reference dose (RfD). The RfD has been developed by the USEPA based on the assumption that thresholds exist for certain toxic effects. In other words, a certain amount (i.e., dose) of the chemical is required to be ingested, inhaled, or absorbed through the skin to produce an undesirable noncancer health effect. In general, the RfD is an estimate of a daily exposure level for the human population, including sensitive populations, which are likely to be without a significant risk of noncancerous effects during a lifetime. The RfD is developed to reflect the duration of exposure, the route of exposure (such as inhalation or ingestion) and is one of the parameters used to develop PRGs.

The RfDs for all contaminants of concern at OU-2 and their associated uncertainty factors, primary target organs, and modifying factors, as published by USEPA in the Integrated Risk Information System (IRIS), the Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997), or Region IX PRG Toxicity Tables (USEPA, 1999), are presented in Table 6-7.

6.1.2.2 Toxicity Assessment for Carcinogenic Effects

Toxicity values have also been developed for evaluating potential human carcinogenic effects from exposure to carcinogens. Potential human carcinogenic effects are evaluated using the chemical-specific slope factor (SF) and accompanying USEPA weight-of-evidence determination. The SF values have been derived by the USEPA based on the concept that for any exposure to a carcinogenic chemical there is always a carcinogenic response (i.e., no threshold level exists). The SF is used in risk assessment to estimate an upper-bound lifetime probability of an individual developing cancer as a result of a specific exposure to a carcinogen and is also one of the parameters used in the development of the PRG. In additions to the SF, as published in IRIS, HEAST, or Region IX PRG Toxicity Tables (USEPA, 1999), the likelihood that a substance is a human carcinogen is also considered. Toxicity information for carcinogenic COCs is presented in Table 6-8.

6.1.2.3 Uncertainty Associated with the Toxicity Assessment

An understanding of the degree of uncertainty associated with toxicity values is an important part of interpreting and using those values. A high degree of uncertainty in the information used to derive toxicity value contributes to less confidence in the assessment of risk associated with exposure to a substance.

The RfDs and SFs, used to develop PRGs, have multiple conservative calculations built into them that can contribute to overestimation of actual risk. For example, factors of up to 10 for four different levels of uncertainty may be incorporated into an RfD and a 95% upperbound confidence estimate derived from the linearized multi-stage carcinogenic model is usually incorporated in the SFs.

In addition, uncertainty arises from the extrapolation of data from high-dose animal studies to low-dose environmental human exposures and may overestimate the risk to human receptors because of the differences in metabolic rates, molecular repair mechanisms or differences in susceptibility.

6.1.3 Risk Characterization

This section presents the results of the streamlined baseline risk assessment for COCs in all relevant exposure media. The risk characterization typically combines information from the exposure assessment and the toxicity assessment to characterize potential noncancer and cancer risks that may be associated with the ingestion, dermal contact, and/or inhalation of site contaminants. Contaminant concentrations were determined from the Site Characterization conducted by Water Management Consultants (1997). The risk characterization presents only a qualitative description of potential risk in accordance with the streamlined approach for municipal landfill recommended by USEPA. In essence, if a detected parameter exceeds a given standard (MCL or non-zero MCLG) in the environmental media tested, an unacceptable risk exists and remedial action is warranted.

Using the streamlined approach, a qualitative estimate of risk is performed. In order to determine that an excess risk is evident, it needs to be demonstrated that there are contaminants that exceed MCLs or non-zero MCLGs. Carcinogenic contaminants exceeding MCLs or non-zero MCLGs that have been identified in the West Lake Landfill include, for groundwater: arsenic, benzene, and vinyl chloride.

Non-carcinogenic contaminants that exceed MCLs or non-zero MCLGs in the West Lake Landfill include for groundwater: iron, manganese, chloride, total dissolved solids, and fluoride. Most of these conventional parameters may reflect background groundwater conditions. Total petroleum hydrocarbons also exceeded the Missouri Department of Natural Resources Tier 1 Cleanup Levels.

Safe Drinking Water Act and State requirements will not allow human consumption of water containing contaminants above their respective MCLs. Based on the presumptive remedy approach for municipal landfills, contaminants were identified in groundwater at concentrations that exceeded their MCLs or non-zero MCLGs. Based on these findings, consideration or remedial action under the presumptive remedy approach is warranted.

6.1.4 Uncertainties Associated with the Risk Characterization and Human Health

The results of this risk characterization should be understood in light of the uncertainties outlined in the data evaluation, exposure assessment, and toxicity assessment. The uncertainties in the information in each of these steps of the risk assessment contribute to uncertainty in the risk characterization.

6.2 Qualitative Ecological Evaluation

The entire area surrounding the West Lake Landfill is rapidly being developed for commercial/light industrial purposes. The area north of the landfill across St. Charles Rock Road, as well as the area west of the landfill in Earth City, has previously been developed. Subsequent to initiation of the OU-2 RI/FS, the areas south and east of the landfill have also undergone extensive commercial/light industrial development. The heavy development in the area has eliminated almost all previously existing plant and animal habitats and has therefore significantly reduced the number and types of potential ecological receptors.

The biological characteristics near the West Lake Landfill were evaluated as part of the West Lake Landfill OU-1 RI/FS. As described in the Site Characterization Summary Report prepared by Engineering Management Support, Inc., dated August 1997, the U.S. Fish and Wildlife Service reported "no federally-listed endangered or threatened species occur in the project area." The Missouri Department of Conservation reported "Department staff examined map and computer files for federal and state threatened and endangered species and determined that no sensitive species or communities are know to occur in the immediate Site or surrounding area." Refer to Section 2.6 for a complete description of species at the Site.

The streamlined risk assessment for OU-2, as discussed in the human health evaluation, has identified groundwater as the primary media of concern. Groundwater is not readily accessible to ecological receptors and the site characterization suggests that groundwater will not adversely impact ecologically sensitive areas. Surface water and sediment sampling results do not indicate off-site release of contaminants from run off and on-site sampling do not suggest that there would be releases through run off in the future.

6.3 Summary and Conclusions of the Baseline Risk Assessment

This OU-2 BRA was prepared in accordance with the presumptive remedy approach for municipal landfills. The USEPA has recognized that certain categories of site – for example, municipal landfill – have similar characteristics, such as types of contaminants, types of disposal practices, or how environmental media are affected (USEPA, 1993b). Based on information acquired from evaluating and cleaning up these sites, USEPA has initiated the use of presumptive remedies to accelerate cleanups at these sites. As part of the presumptive remedy approach, the BRA may be streamlined to facilitate action to address obvious threats to human health or the environment.

Field investigative activities for OU-2 were designed to meet the objectives of Section 3.1 of the Statement of Work (SOW). As described in the EPA-approved *Remedial Investigation/Feasibility Study Work Plan, West Lake Landfill Operable Unit 2, Bridgeton, Missouri (Work Plan), Appendix A-01, Field Sampling Plan* prepared by Golder Associates, Inc. (Golder, 1995b), the primary objectives of the West Lake Landfill Operable Unit 2 (OU-2) RI were to collect data on and adjacent to OU-2 regarding environmental characteristics, chemical occurrence, potential chemical migration pathways, and transport mechanisms. These data were used in the evaluation and qualitative assessment of risk associated with exposures to contaminants present at the OU-2 site and are summarized in Sections 6.1 and 6.2 of the BRA.

The phased approach to site characterization is a site-specific strategy that frames the data collection effort within the context of determining whether a risk is present at a site rather than characterizing the nature and extent of all contamination at a landfill (USEPA, 1991b). The West Lake Landfill OU-2 RI and Site Characterization efforts sampled a variety of environmental media for landfill contaminants. Groundwater was the medium most extensively sampled as part of the West Lake Landfill Site Characterization and presented parameters above detection limits, including, but not exclusive to, organics and metals which were further evaluated in the risk assessment.

The streamlined approach to evaluating risks at CERCLA municipal landfill sites differed from the typical baseline risk assessment in that quantitative calculations of intakes and risks were not conducted. Instead, pathways that were an obvious threat to human health and the environment were identified by comparing site-specific contaminant concentrations to standards or risk-based chemical concentrations (USEPA, 1991b). Standards and risk-based chemical concentrations were both used in this streamlined BRA for OU-2. Standards used included maximum contaminant levels (MCLs) and non-zero maximum contaminant level goals (MCLGs) as presented in 40 CFR 141. Risk-based chemical concentrations were developed using standard default exposure assumptions, USEPA toxicity data and target cancer risks or target hazard quotients. The risk-based concentrations used in the streamlined BRA for OU-2 were the USEPA Region 9 Preliminary Remediation Goals (PRGs).

Groundwater had both potential chemical-specific standards (i.e., MCLs or non-zero MCLGs) and PRGs. Only PRGs were available to evaluate the other media. Maximum concentrations of detected contaminants in a medium were compared to the MCL, non-zero MCLG, or PRG. This serves as a conservative evaluation to identify potential impacts to human health because the maximum concentration was not present at all locations. For the OU-2 BRA, (and consistent with the streamlined approach recommended by USEPA (USEPA, 1991b)), if the site specific contamination concentration of a confirmed parameters exceeded a standard (i.e., MCL or non-zero MCLG), it was considered a Contaminant of Concern for risk assessment. If not standard existed, then the site-specific contaminant concentration was compared to a PRG based on maximum beneficial use, which is residential use of the medium. Residential use is an unrealistic worst-case scenario for the site, based on the rationale provided i the Baseline Risk Assessment, Section 2.7.7. Contaminants that exceeded a PRG but did not exceed an existing standard were not considered Contaminants of Concern.

Groundwater sampling results showed that the alluvial hydrogeologic unit contained a larger number of COCs when compared to the other hydrogeologic units, which was not unexpected given its closer proximity to the inactive landfill contaminants. Detected parameters which exceeded MCLs or non-zero MCLGs for the alluvial hydrogeologic unit (as well as all other hydrogeologic units) are presented in Section 4.2.3. The majority of the inorganic and conventional parameters that exceeded MCLs or non-zero MCLGs in the sampled hydrogeologic units can be explained by variations in background. However, organic COCs in the alluvial hydrogeologic unit exceeded MCLs and non-zero MCLGs by such a factor as to warrant consideration of remedial action under the presumptive remedy approach. In addition, the majority of the parameters that exceeded MCLs and/or non-zero MCLGs were near the inactive landfill in the immediate vicinity of MW-F2.

Soil data collected as part of the West Lake Landfill Site Characterization did not have any parameters that exceeded recommended PRGs. Therefore, there were not contaminants of concern identified for this medium.

Leachate sampling of the West Lake Landfill as part of the Site Characterization identified a minimal number of contaminants. There are no standards for leachate constituents and comparison to PRGs based on drinking water is not appropriate because leachate is not used as a drinking water source. Parameters detected in leachate were useful for identification of contaminants that could impact groundwater used as a drinking water source. Two contaminants were identified in leachate that are also COCs in groundwater. They are arsenic and benzene. In general, the leachate from the inactive landfill had fewer detected parameters and at lower concentrations than the active landfill. This is probably due to its greater age. The leachate sampling results also do not support the USEPA concern that liquid hazardous waste disposal occurred in the inactive landfill.

Landfill gas monitoring conducted as part of the West Lake Landfill Site Characterization identified sporadic, isolated landfill gas impacts that are typical for a solid waste landfill. There were other compounds detected in the landfill gas that are often not reported in typical landfill gas. However, these compounds were present at low concentrations and do not suggest a definable source of hazardous substances that is emitting significant vapors into the inactive landfill gas. PRGs were not used to evaluate landfill gas for this streamlined BRA. It is unlikely that any individual would be exposed to these parameters identified in the landfill gas under conditions on which the PRGs are based. Furthermore, exposures will likely occur for short periods of time during routine maintenance and/or landfill gas monitoring activities. Given these factors, the parameters detected in the landfill gas are unlikely to pose an exposure concern at the detected levels.

In the streamlined approach being used for this BRA, only a qualitative estimate of risk was needed. In essence, if a detected parameter exceeded a given standard (MCL or non-zero MCLG) in the environmental media tested, an unacceptable risk exists and remedial action may be warranted. This approach does not consider the fact that there is no current drinking water use of groundwater near the landfill at this time.

Carcinogenic contaminants exceeding MCLs or non-zero MCLGs which were identified in the alluvial groundwater sampling for the West Lake Landfill included: arsenic, benzene, and vinyl chloride.

Non-carcinogenic contaminants that exceeded MCLs or non-zero MCLGs in the West Lake Landfill included, for groundwater: iron, manganese, chloride, total dissolved solids, and fluoride. However, most of these conventional parameters appear to reflect background groundwater conditions. Total petroleum hydrocarbons also exceeded the Missouri Department of Natural Resources Tier 1 Cleanup Levels.

A qualitative ecological evaluation was conducted for OU-2. Although local populations of some common species may be present in the area, OU-2 is not highly sensitive or ecologically unique environment. The streamlined risk assessment for OU-2, as discussed in the human health evaluation, identified groundwater as the primary media of concern. Groundwater is not readily accessible to ecological receptors and the site characterization suggests that groundwater will not adversely impact ecologically sensitive areas. Surface water and sediment sampling results do not indicate off-site release of contaminants from run-off and on-site sampling do no suggest that there would be releases through run off in the future.

In conclusion, Safe Drinking Water Act and State requirements will not allow human consumption of water containing contaminants above their respective MCLs or MCLGs. There is also no current or anticipated future drinking water use of the groundwater near the landfill. Using the presumptive remedy approach for municipal landfill, both carcinogenic and non-carcinogenic contaminants were identified in groundwater at concentrations that exceeded their MCLs or non-zero MCLGs. Based on these findings, consideration of remedial action under the presumptive remedy approach is warranted.

7.0 TREATABILITY TESTING

As described in EPA Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, 1988, the phased RI/FS process is intended to better focus the site investigation so that only those data necessary to support the RI/FS and the decision-making process are collected. Data needs are initially identified on the basis of the understanding of the site at the time the RI/FS is initially scoped. To the extent possible, data required to assess the feasibility of technologies should be gathered during the site characterization. Because data requirements will depend on the specific treatment process and the contaminants and matrices being considered, the results of the site characterization will influence the types of alternatives developed and screened, which will in turn influence additional data needs. Should existing site and/or treatment data be insufficient to adequately evaluate alternatives, treatability tests may be necessary to evaluate a particular technology on specific site wastes.

Site-specific information collected during the site characterization is adequate to evaluate remedial alternatives for the OU-2 Site. Under the presumptive remedy, the data presented in this report are sufficient to evaluate remedial alternatives potentially applicable to this site, and treatability testing is not necessary.

8.0 SUMMARY

The OU-2 RI was conducted to characterize the affected media, location, types, and physical state, and concentration of contaminants, and to describe the extent of contamination migration. The OU-2 objectives were met by defining site physical and biological characteristics, site hydrogeologic characteristics, sources of contamination, surface and sediment quality, and air quality. Site physical characteristics were presented in detail in the *Physical Characterization Memorandum* previously submitted to EPA. Site biological characteristics were sufficiently by OU-1 RI activities. Site hydrogeologic characteristics described in *Physical Characterization Memorandum* were supplemented with detailed groundwater quality assessment. Source characterization activities included installation of leachate risers to characterize leachate quality in the active and inactive landfills, as well as landfill gas analyses conducted as part of health and safety monitoring and by the analytical laboratory. Surface water and sediment sampling provided reliable data regarding potential groundwater impacted on adjacent surface waters and sediments.

Based on the extensive data collected as part of the OU-2 RI, no hazardous substance source areas were identified. The active sanitary landfill maintains an inward hydraulic gradient, drawing surrounding groundwater into leachate collection sumps. The inactive landfill leachate quality is similar to the active sanitary landfill leachate quality and does not include solvent compounds that might be associated with disposal of hazardous substances. Landfill gas in the inactive landfill is typical of solid waste landfills.

Groundwater quality in the Deep Salem and St. Louis/Upper Salem hydrogeologic units near and within OU-2 is similar to upgradient, background groundwater quality, indicating a lack of impacts to these units. With the exception of a limited area along the western portion of the inactive landfill near monitoring well MW-F2 area west of the asphalt plant LUST site, and selected locations within the site boundaries, the alluvial groundwater quality near the site is also similar to upgradient, background quality. Volatile organic compounds, useful indicators of liquid hazardous substance disposal and solid waste leachate/gas impacts, were detected only infrequently and at low concentrations. Landfill gas has been documented to affect groundwater quality in at least one well, and may influence groundwater quality throughout the site area. An isolated area in the southwestern portion of the site, near the monitoring well MW-F2 area west of the asphalt plant LUST site, exhibited a wider range of volatile organic compounds and petroleum hydrocarbons, suggesting potential impacts.

Surface water and sediment results indicate that groundwater is not significantly impacting downgradient surface waters and sediments, including the area immediately downgradient of the MW-F2 area.

Quality assurance results, including field quality assurance such as equipment blanks, field blanks, trip blanks, and field duplicate samples; split laboratory results; and internal laboratory quality assurance samples such as matrix spikes and matrix spike duplicates indicate that a high level of confidence can be placed on the data generated during the OU-2 RI.

The Safe Drinking Water Act and State requirements will not allow human consumption of water containing contaminants above their respective MCLs or MCLGs. There is also no current or anticipated future drinking water use of the groundwater near the landfill. Using the presumptive remedy approach for municipal landfill, both carcinogenic and non-carcinogenic contaminants were identified in groundwater at concentrations that exceeded their MCLs or non-zero MCLGs. Based on these findings, consideration of remedial action under the presumptive remedy approach is warranted.

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Tables

Table 2-1. Previous Investigation Summary
West Lake Landfill

Year(s)	Investigation Conducted for:	Description
1973	West Lake Landfill	Four wells at unknown locations were sampled for five sampling rounds; samples were analyzed for general inorganic parameters, metals, and phenols
1976	West Lake Quarry	Three wells along the western property boundary were sampled in one sampling round; samples were analyzed for general inorganic parameters, metals, and phenols
1976 – 1984	West Lake Quarry	Wells around the perimeter of the inactive landfill on the western portion of the site, and after 1981 near the leachate retention pond, were sampled intermittently. Samples were analyzed for a varying list of parameters which included general inorganic parameters, ions, metals, and radionuclides.
1979 – 1982	Missouri Department of Natural Resources	Wells around the perimeters on the inactive landfill and the perimeter of the site, as well as site surface water bodies and off-site private wells, were sampled intermittently. The samples were analyzed for a varying list of general inorganics parameters, ion, metals, and radionuclides.
1982	Nuclear Regulatory Commission	The *Radiological Survey of the West Lake Landfill, St. Louis County, Missouri* identified two areas of radiological contamination on-site, and concluded that there is no indication of off-site migration of the contamination.
1983	College of Engineering University of Missouri – Columbia	The *Engineering Evaluation of Options for Disposition of Radioactively Contaminated Residues Presently in the West Lake Landfill, St. Louis County, Missouri, Draft* identified radiological contamination and concluded that radon gas release from the site would increase.
1984	Nuclear Regulatory Commission	The perimeter berm around the northern extent of the site was surveyed for radiological contamination and inspected for erosion. Migration of contamination and slope failure were observed on selected portions of the berm west of OU-2 Area 2.
1986	West Lake Landfill	Existing and new wells around the inactive landfill on the western portion of the site, and the leachate retention pond, were included in a thorough hydrogeologic investigation. The hydrogeologic characterization concluded that three levels of the alluvial aquifer (shallow, intermediate, and deep) were in complete communication, and that groundwater flow was generally towards the northwest. Groundwater samples were collected and analyzed for volatile organic compounds, acid-base neutral extractables, pesticides, and polychlorinated biphenyls, phenol, cyanide, and metals. Concentrations of certain parameters exceeded applicable standards, but the distribution was erratic and generally could not be attributed specifically to site activities. Concentrations of parameters which exceeded standards were likely to be diluted below standards prior to exposure to any downgradient uses. (BMD, 1986)

Table 2-1. Previous Investigation Summary (continued)
West Lake Landfill

Year(s)	Investigation Conducted for:	Description
1986	Nuclear Regulatory Commission	Eighteen groundwater monitoring wells were sampled and analyzed for radionuclides.
1989 and 1991	Environmental Protection Agency	A review of historical aerial photographs, from 1941 through 1991, was conducted to identify areas of potential environmental concern. Solid waste and mine spoils areas were identified.
1989 – present	Laidlaw Waste Systems/ Bridgeton Landfill, LLC	Groundwater samples were collected from wells throughout the site on an intermittent basis, focusing specifically on wells around the active landfill area in recent years. Samples were analyzed for a variable list of parameters, including general inorganics, metals, radionuclides, volatile organic compounds, pesticides, herbicides, polychlorinated biphenyls, cyanide, and phenol.
1990 – 1991	Earth City Industrial Park	An investigation of potential radiological impacts to neighboring properties was conducted in three phases. Radiological contamination reportedly originating from OU-1 Area 2 was identified in soil at two hot spots hear the property boundary.
1991	Agency for Toxic Substances and Disease Registry	A review of available information concluded that the site presented no apparent health hazard, although exposure could occur if groundwater contamination increased and migrated off-site.
1991	Laidlaw Waste Systems	A subsurface soil gas survey conducted in the vicinity of MW-F2 identified BTEX and TPH impacts to subsurface oils in an area extending 150 feet north and 300 feet south of MW-F2.
1992	Laidlaw Waste Systems	An environmental investigation for the development of a site Health and Safety Plan identified radon in the landfill gas collection system.
1992	Laidlaw Waste Systems	The slope of the berm along the western portion of the inactive landfill was reworked to 3H:1V, recovered and revegetated.
1993	Laidlaw Waste Systems	A health impact assessment concluded that radiological contaminants from site sources were not a threat to site workers, the general public, or the environment.
1994	Laidlaw Waste Systems	A health assessment analyzed chemical constituents of the landfill gas collection system and concluded that landfill gas composition was similar to EPA-reported averages, and that exposures to site workers were below analytical detection limits.
1994	Operable Unit 1 Respondent Group	An overland gamma survey conducted in and in the immediate vicinity of OU-1 identified radiologically contaminated hot spots both inside and outside of OU-1 boundaries, and recommended alteration of those boundaries.
1995	Laidlaw Waste Systems	OU-2 *RI/FS Work Plan* (Golder, April 1995) submitted according to Administrative Order on Consent

Table 2-1. Previous Investigation Summary (continued)
West Lake Landfill

Year(s)	Investigation Conducted for:	Description
1996	Operable Unit 1 Respondent Group	*Overland Gamma Survey Report* for OU-1 Areas 1 and 2 (McLaren-Hart, April 1996) described the methods and results of an overland gamma survey conducted in Radiological Areas 1 and 2 to identify the approximate extent of radiological materials and hot spots, to guide subsequent investigative activities.
1996	Laidlaw Waste Systems	OU-2 *Physical Characterization Technical Memorandum* (Golder, August 1996) presented the results of field activities performed in accordance with the April 1995 Work Plan (Golder).
1996	Operable Unit 1 Respondent Group	*Split Soil and Groundwater Sampling Data Summary Report* for OU-1 Areas 1 and 2 (McLaren-Hart, November 1996) discussed the results of analysis of soil boring samples that had been archived plus supplemental groundwater samples.
1996	Operable Unit 1 Respondent Group	*Soil Boring/Surface Soil Investigation Report* for OU-1 Areas 1 and 2 (McLaren-Hart, November 1996) discussed data obtained from soil borings drilled and samples with Radiological Areas 1 and 2.
1996	Operable Unit 1 Respondent Group	*Groundwater Conditions Report* for OU-1 Areas 1 and 2 (McLaren-Hart, November 1996) discussed data obtained from the installation, sampling, and aquifer testing at monitoring wells in and adjacent to Radiological Areas 1 and 2.
1996	Operable Unit 1 Respondent Group	*Rainwater Runoff, Erosional Sediment, Surface Water, and Leachate Sampling* for OU-1 Areas 1 and 2 (McLaren-Hart, November 1996) discussed the methodology for collection and the results of rainwater runoff, erosional sediment, surface water, and leachate seep sampling from Radiological Areas 1 and 2.
1996	Operable Unit 1 Respondent Group	*Radon Gas, Landfill Gas, and Fugitive Dust Report* for OU-1 Areas 1 and 2 (McLaren-Hart, November 1996) discussed the data from radon concentration measurements, soil vapor, surface soil, and fugitive dust sampling within Radiological Areas 1 and 2.
1997	Operable Unit 1 Respondent Group	*Interim Investigative Technical Memorandum* for OU-1 (Engineering Management Support, January 1997) described the methods used in various OU-1 site characterization activities.
1997	Operable Unit 1 Respondent Group	*Site Characterization Summary Report* for OU-1 (Engineering Management Support, August 1997) presented results of various site characterization activities, for use in completing the Remedial Investigation, Baseline Risk Assessment, and Feasibility Study for OU-1.
1997	Operable Unit 1 Respondent Group	*Investigative Derived Waste Management and Interim Remedial Measures Plan* for OU-1 (Engineering Management Support, September 1997) discussed options for managing investigative derived materials.

Table 2-1. Previous Investigation Summary (continued)
West Lake Landfill

Year(s)	Investigation Conducted for:	Description
1997	Laidlaw Waste Systems	OU-2 *Site Characterization Summary Report* (Water Management, December 1997) presented the results of site characterization activities conducted as part of the OU-2 Remedial Investigation/Feasibility Study.
1998	Operable Unit 1 Respondent Group	*Baseline Risk Assessment* for OU-1 (Auxier, March 1998)
2000	Operable Unit 1 Respondent Group	*Draft Feasibility Study Report* for OU-1 (Engineering Management Support, February 2000) presented an evaluation of potential remedial options for OU-1, to ensure protection of human health and the environment and to assess each alternative in terms of evaluation criteria prescribed by the NCP.
2000	Laidlaw Waste Systems	OU-2 *Baseline Risk Assessment* (Globaltox, February 2000) provided an assessment of baseline health risks and environmental impacts.
2000	Operable Unit 1 Respondent Group	*Remedial Investigation Report* for OU-1 (Engineering Management Support, April 2000) presented the results of various OU-1 site characterization activities, including site conditions, sources of contaminants, nature and extent of contamination and associated impacts, and fate and transport of the contaminants.
2000	Laidlaw Waste Systems Operable Unit 2	Remedial Investigation Report for OU-2 presented the results of site characterization activities, including chemical characterization of various environmental media at the site.
2002	Operable Unit 1 Respondent Group	Revised Draft Feasibility Study Report
2004	Operable Unit 1 Respondent Group	Revised FS Report for OU-1
2005	Operable Unit 1 Respondent Group	Revised FS Report for OU-1

Table 2-2. Historical Precipitation Survey, West Lake Landfill

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1961	0.39	2.06	4.75	3.47	7.25	3.67	6.2	1.88	4.01	2.67	2.9	1.95	41.2
1962	3.56	2.53	3	2.52	2.44	4.75	5.49	2.29	2.63	2.7	0.71	1.99	34.61
1963	0.74	0.25	5.54	1.98	4.77	3.87	1.37	2.55	1.13	2.85	2.9	0.67	28.62
1964	1.7	2.3	3.84	4.99	2.68	2.73	4.25	2.39	1.47	0.73	3.84	1.24	32.16
1965	2.51	1.16	2.34	3.67	1.38	3.03	3.17	3.59	3	0.46	0.78	3.17	28.26
1966	0.65	4.12	1.09	6.03	4.59	1.59	1.26	3.72	2.15	2.18	2.47	2.49	32.34
1967	2.89	1.72	2.77	3.4	4.73	4.46	3.84	1.36	4.33	3.45	2.15	6.2	41.3
1968	1.86	1.09	2.06	1.48	6.78	0.9	3.92	1.6	3.74	0.69	5.74	2.63	32.49
1969	3.61	2.04	2.47	4.01	2.11	8.65	7.08	0.52	5.03	5.77	0.44	1.99	43.72
1970	0.22	0.64	2.17	9.09	2.04	5.08	0.6	6.44	5.54	2.21	0.77	1.4	36.2
1971	0.66	3.08	1.81	1.65	5.66	2.43	4.7	0.08	3.98	1.51	1.67	6.5	33.73
1972	0.77	0.74	2.93	4.49	1.02	1.19	3.1	2.69	6.21	1.47	5.59	3.54	33.74
1973	1.4	1.04	5.81	4.25	3.92	4.23	2.85	2.46	3.52	2.33	3.65	4.36	39.82
1974	3.51	4.17	2.58	2.4	5.9	3.45	0.9	5.05	2.5	1.51	3.15	1.71	36.83
1975	5.38	3.59	4.08	4.56	3.23	3.78	2.56	5.44	2.48	0.21	2.62	2.28	40.21
1976	0.83	1.08	4.28	1.37	3.9	2.32	2.28	1.27	0.9	3.37	0.73	1.13	23.46
1977	2.38	2.47	6.28	0.99	2.13	5.47	4.28	5.34	3.64	3.76	4.33	2.34	43.41
1978	1.7	1.6	6.67	3.21	3.69	2.39	6.03	0.76	3.1	2.28	4.47	1.81	37.71
1979	1.95	1.48	3.63	7.47	1.62	1.67	3.67	2.26	T	1.81	2.07	1.85	29.48
1980	0.63	1.54	3.98	1.54	3.4	2.19	3.56	2.72	3.12	2.89	1.25	0.66	27.48
1981	0.64	2.18	2.97	3.4	6.79	5.82	10.71	3.31	1.14	3.81	2.71	2.01	45.52
1982	4.9	1.37	2.88	2.55	4.85	5.96	7.91	5.27	5.27	2.3	3.89	7.82	54.97
1983	0.72	0.95	3.54	7.3	6.32	4.32	1.23	2.24	1.24	5.4	7.79	3.75	44.8
1984	0.84	3.43	5.37	6.29	5.19	2.74	0.76	0.64	8.88	7.12	5.5	4.89	51.65
1985	0.53	3.77	5.18	3.6	3.3	9.43	5.23	3.66	0.43	1.96	9.95	3.69	50.73
1986	0.1	4.68	1.22	1.23	2.42	4.43	2.61	2.22	7.99	5.34	1.58	1.06	34.88
1987	1.98	1.4	2.16	1.74	2	3.59	5.04	5.56	1.62	1.74	4.09	7.46	38.38
1988	3.3	2.27	4.73	1.15	1.44	1.97	3.02	2.31	1.99	1.86	6.65	3.24	33.93
1989	2.58	1.43	4.53	2.1	4.11	2.34	4.59	3	1.69	0.95	0.59	0.69	28.6
1990	1.42	3.53	2.66	3.07	9.59	3.02	3.34	2.84	0.78	4.96	3.36	6.52	45.09
1991	1.52	0.98	3.2	3.27	3.87	0.44	5.18	0.98	2.98	5.7	3.26	2.1	33.48
1992	1.12	1.89	3.45	2.46	1.45	1.19	4.31	3.45	2.98	1.21	6.32	3.66	33.49
1993	3.54	2.75	3.31	6.16	3.94	7.12	5.06	4.78	9.16	2.61	4.85	1.48	54.76
1994	2.09	1.51	1.27	10.32	1.72	2.16	1.42	3.76	1.18	2.85	4.9	1.52	34.7
1995	4.39	1.33	3.19	3.33	12.92	2.96	2.16	4.52	0.74	2.01	1.28	2.85	41.68
1996	3.27	0.52	3.06	7.97	4.34	3.72	6.33	1.57	2.86	2.67	6.5	0.86	43.67
1997	2.74	4.14	2.85	2.66	3.05	2	1.44	3.36	2.73	2.05	2.36	1.85	31.23
1998	2.88	2.93	6	4.63	3.62	6.9	6.39	2.35	1.86	2.51	2.72	0.83	43.62
1999	5.1	3.52	2.4	3.72	2.2	5.26	4.22	1.95	1.09	2.04	0.72	1.84	34.06
2000	1.23	3.11	1.88	1.84	5.84	8.22	2.25	3.64	2.62	2.6	2.79	1.35	37.37
2001	1.12	2.48	1.45	3.01	2.81	3.6	4	1.99	2.81	5.5	3.06	3.46	35.29
2002	3.16	0.83	3.67	4.25	7.81	5.26	1.47	4.12	2.44	4.78	1.14	2.02	40.95
2003	0.96	2	2.8	4.29	3.97	12.35	2.51	2.54	4.15	2.81	5.34	2.34	46.06

Table 2-2. Historical Precipitation Survey, West Lake Landfill (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2004	3.97	0.85	4.36	1.94	9.75	0.83	5.52	4.1	0.23	3.21	5.74	1.77	42.27
2005	9.01	1.84	1.47	2.17	0.78								
Record Mean	2.23	2.1	3.37	3.71	4.16	3.94	3.81	2.92	2.99	2.79	3.39	2.7	38.14

Notes:
T = Trace
Station Locator: St. Louis/Lambert International Airport
Data from 1961-2005 found on http://www.crh.noaa.gov/lsx/climate/STL/month_season_totals.htm

Table 2-3. Generalized Stratigraphic Column

System	Series	Group	Formation	Thickness (ft)	Dominant Litholoy	Water-Bearing Character
Quaternary	Holocene		Alluvium	0-150	Sand, gravel, silt, and clay.	Some wells yield more than 2,000 gpm
	Pleistocene		Loess	1-110	Silt.	Essentially not water yielding.
			Glacial Till	0-55	Pebbly clay and silt.	
Pennsylvanian	Missourian	Pleasanton	Undifferentiated	0-75	Shales, siltstone, "dirty" sandstones, coal beds and thin limestone beds.	Generally yields very small quantities of water to wells. Yields range from 0 to 10 gpm.
	Desmoinesian	Marmaton	Undifferentiated	0-90		
		Cherokee	Undifferentiated	0-200		
	Atokan		Cheltemham Formation	Unknown		
Mississippian	Meramecian		Ste. Genevieve Formation	0-160	Argillaceous to arenaceous limestone.	Yields small to moderate quantities of water to wells. Yields range from 5 to 50 gpm. Higher yields are reported for this interval locally.
			St. Louis Limestone	0-180		
			Salem Formation	0-180		
			Warsaw Formation	0-110	Shales in upper portion, limestone in lower portions.	
	Osagean		Burlington-Keokuk Limestone	0-240	Cherty limestone.	
			Fern Glen Formation	0-105	Red limestone and shale.	
	Kinderhookian	Chouteau	Undifferentiated	0-122	Limestone, dolomitic limestone, shale and siltstone.	
Devonian	Upper	Sulphur Springs	Bushberg Sandstone	0-60	Limestone and sandstone	
			Glen Park Limestone			
			Grassy Creek Shale	0-50	Fissile, carbonaceous shale	
Silurian			Undifferentiated	0-200	Cherty limestone	
Ordovician	Cincinnation		Maquoketa Shale	0-163	Silty, calcareous or dolomitic shale.	Probably constitutes a confining influence on water movement.
			Cape Limestone	0-5	Argillaceous limestone.	Yields small to moderate quantities of water to wells. Yields range from 3 to 50 gpm. Decorah Formation probably acts as a confining bed locally.
	Champlainian		Kimmswick Formation	0-145	Massive limestone.	
			Decorah Formation	0-50	Shale with interbedded limestone.	
			Plattin Formation	0-240	Finely crystalline limestone.	
			Rock Levee Formation	0-93	Dolomite and limestone, some shale.	
			Joachim Dolomite	0-135	Primarily argillaceous dolomite.	
			St. Peter Sandstone	0-160	Silty sandstone, cherty limestone grading upward into quartzrose sandstone.	Yields moderate quantities of water to wells. Yields range from 10 to 140 gpm.
			Everton Formation	0-130		
	Canadian		Powell Dolomite	0-150	Sandy and cherty dolomites and sandstone.	Yields small to large quantities of water to wells. Yields range from 10 to 300 gpm. Upper part of aquifer group yields only small amounts of water to wells.
			Cotter Dolomite	0-320		
			Jefferson City Dolomite	0-225		
			Roubidoux Formation	0-177		
			Gasconade Dolomite Gunter Sandstone Member	0-280		
Cambrian	Upper		Eminence Dolomite	0-172	Cherty dolomites, siltstones, sandstone, and shale.	Yields moderate to large quantities of water to wells. Yields range from 10 to 400 gpm.
			Potosi Dolomite	0-325		
		Elvins	Derby-Doerun Dolomite	0-165		
			Davis Formation	0-150		
Precambrian					Igneous and metamorphic rocks.	Does not yield water to wells in this area.

Notes:
Basal part of alluvium may be Pleistocene age.
Stratigraphic nomenclature may not necessarily be that of the U.S. Geological Survey.
Aquifers most favorable as water sources are shaded.
Double-line indicates unconformity.

Source:
Water Resources of the St. Louis Area, Missouri. (Miller et al., 1974)

Table 3-1. Piezometer and Leachate Riser Summary, West Lake Landfill

Piezometer	Location		Elevation		Screened Interval					Surface Casing		
					Depth		Screen	Elevation				
	Northing	Easting	Top of PVC	Ground Surface	Bottom	Top	length	Bottom	Top	Diameter	Depth	Rationale
PZ-100-SS	1068867.81	517175.03	485.84	484.4	93.60	73.96	19.6	390.75	410.39	NA		
PZ-100-SD	1068851.79	517195.45	485.82	484.4	244.60	234.80	9.8	239.75	249.55	NA		
PZ-100-KS	1068842.03	517211.63	485.64	483.8	383.80	374.00	9.8	99.96	109.76	NA		
PZ-101-SS	1068472.89	516622.94	476.68	474.9	139.28	129.48	9.8	335.61	345.41	NA		
PZ-102-SS	1068087.67	516887.97	483.85	482.1	89.50	79.70	9.8	392.55	402.35	NA		
PZ-102R-SS	1068131.86	516858.81	485.58	484.5	89.63	79.83	9.8	394.87	404.67	NA		
PZ-103-SS	1067660.40	516723.54	480.17	477.8	144.50	134.70	9.8	333.28	343.08	NA		
PZ-104-SS	1067028.01	516847.19	483.63	481.6	144.30	134.50	9.8	337.26	347.06	NA		
PZ-104-SD	1067013.26	51684.43	483.69	482.1	245.00	235.20	9.8	237.10	246.90	NA		
PZ-104-KS	1066993.15	516820.50	484.04	482.3	407.17	397.37	9.8	75.15	84.95	6 in.	1.00-249.00	isolate formations above Warsaw Formation
PZ-105-SS	1066421.35	516230.23	483.61	481.2	148.30	138.50	9.8	332.92	342.72	6 in.	1.50-45.00	isolate wet sands
PZ-106-SS	1066726.29	515399.94	462.70	461.0	165.10	155.30	9.8	295.85	305.65	NA		
PZ-106-SD	1066715.14	515415.96	463.42	461.5	200.59	190.79	9.8	260.86	270.66	NA		
PZ-106-KS	1066703.87	515432.10	464.26	461.8	373.57	363.75	9.8	88.20	98.02	6 in.	1.00-204.00	isolate formations above Warsaw Formation
PZ-107-SS	1067163.45	515254.52	464.66	162.6	102.40	92.60	9.8	360.23	370.03	6 in.	1.00-55.00	isolate waste and fine sands
PZ-108-SS	1067678.37	515972.61	456.20	454.1	143.35	133.54	9.8	310.77	320.58	NA		
PZ-109-SS	1068011.70	516144.36	458.50	456.8	135.50	125.70	9.8	321.27	331.07	NA		
PZ-110-SS	1068336.09	515919.72	458.91	456.8	110.70	100.90	9.8	346.14	355.94	6 in.	1.00-61.00	isolate fine sands
PZ-111-SD	1068638.11	515834.57	461.55	459.2	209.20	199.40	9.8	250.02	259.82	6 in.	1.00-98.00	isolate fine sands
PZ-111-KS	1068620.78	515851.23	460.87	159.2	366.96	357.15	9.8	92.22	102.03	10 in. 6 in.	0.50-83.80 1.00-215.30	isolate fine sands isolate formations above Warsaw Formation
PZ-112-AS	1069002.00	515674.01	459.83	457.9	34.40	29.60	4.8	423.53	428.33	NA		
PZ-113-AS	1069224.31	51547.72	461.42	459.9	38.70	28.90	9.8	421.22	431.02	NA		
PZ-113-AD	1069233.33	515759.85	461.46	459.9	108.40	98.60	9.8	351.46	361.26	NA		
PZ-113-SS	1069242.39	515776.57	461.77	460.0	158.37	148.57	9.8	301.59	311.39	6 in.	0.50-115.00	isolate alluvial sands
PZ-114-AS	1067418.88	516768.25	451.31	449.8	29.70	19.90	9.8	420.08	429.88	NA		
PZ-115-SS	1069408.54	516755.35	452.30	450.6	84.48	74.68	9.8	366.13	375.93	6 in.	1.00-39.00	isolate alluvial sands
PZ-116-SS	1066410.28	515843.88	484.87	483.1	161.00	151.40	9.6	322.07	331.67	NA		
PZ-200-SS	1068496.19	516972.20	485.63	483.6	97.64	9.62	88.0	385.97	473.99	NA		
PZ-201-SS	1067819.55	516862.06	480.33	478.0	88.31	9.75	78.6	389.70	468.26	NA		
PZ-201A-SS	1067831.76	516846.40	480.16	478.4	89.80	80.00	9.8	388.55	398.35	NA		
PZ-202-SS	1067320.25	517101.58	481.17	479.0	89.10	40.20	48.9	389.91	438.81	6 in.	1.00-34.00	isolate fine sands
PZ-203-SS	1066661.50	516607.70	486.59	484.2	109.40	99.60	9.8	374.78	384.58	6 in.	1.00-56.10	isolate alluvial sands
PZ-204-SS	1066426.61	515533.49	469.63	467.0	89.35	10.95	78.4	377.68	456.08	NA		
PZ-204A-SS	1066529.82	515556.28	468.16	466.7	89.10	79.50	9.6	377.56	387.16	NA		
PZ-205-AS	1067463.60	515463.34	460.99	459.3	48.35	38.55	9.8	410.98	420.78	10 in.	0.50-29.00	isolate waste
PZ-205-SS	1067483.54	515477.78	461.78	459.5	98.37	88.57	9.8	360.96	370.76	6 in.	1.00-54.00	isolate waste and fine sands
PZ-206-SS	1068030.83	515809.45	460.20	458.4	124.80	115.00	9.8	333.58	343.38	6 in.	1.00-52.00	isolate fine sands and potential UST impacts
PZ-207-AS	1069644.67	516037.64	463.57	461.9	39.70	34.90	4.8	422.18	426.98	NA		
PZ-208-SS	1069219.14	517169.45	474.25	472.5	98.50	88.70	9.8	374.03	383.83	NA		
PZ-300-AS	1065498.44	513867.83	450.66	448.5	19.70	9.90	9.8	428.80	438.60	NA		
PZ-300-AD	1065213.84	513828.06	449.62	448.1	41.90	37.10	4.8	406.20	411.00	NA		
PZ-300-SS	1065204.75	513849.81	449.60	448.4	93.70	83.90	9.8	354.70	364.50	6 in.	0.80-46.00	seal off alluvial materials

Table 3-1. Piezometer and Leachate Riser Summary, West Lake Landfill

Piezometer	Location		Elevation		Screened Interval					Surface Casing		
					Depth		Screen	Elevation				
	Northing	Easting	Top of PVC	Ground Surface	Bottom	Top	length	Bottom	Top	Diameter	Depth	Rationale
PZ-301-SS	1064801.68	515516.99	514.71	513.1	106.70	150.90	-44.2	352.40	362.20	NA		
PZ-302-AS	1067197.73	514737.29	451.42	449.2	22.00	12.20	9.8	427.20	437.00	NA		
PZ-301-AI	1067210.24	514720.49	451.15	450.0	42.40	32.60	9.8	407.60	417.40	NA		
PZ-303-AS	4167763.32	514425.53	453.18	450.8	25.80	16.00	9.8	425.00	434.80	NA		
PZ-304-AS	1068146.47	514434.57	453.71	451.4	26.90	17.10	9.8	424.50	434.30	NA		
PZ-304-AI	1068125.91	514434.70	454.02	451.6	48.80	39.00	9.8	402.80	412.60	NA		
PZ-305-AI	1068064.93	515633.57	459.28	547.6	63.00	53.20	9.8	394.60	404.40	NA		
PZ-1201-SS	1067302.42	516903.56	482.42	480.4	147.30	137.70	9.6	333.11	342.71	NA	2.60-53.00	seal off alluvial materials
Leachate Riser												
LR-100	1067293.73	514893.56	469.12	467.2	24.50	19.70	4.8	442.70	447.50	NA		
LR-101	1068402.25	514718.41	NA	NA	NA	NA	NA	NA	NA	NA		well not installed
LR-102	1068937.21	514788.13	513.52	512.0	59.70	54.90	4.8	452.30	457.10	NA		
LR-103	1068527.38	515217.07	461.28	460.1	38.40	28.60	9.8	421.70	431.50	NA		
LR-104	1068078.63	515623.34	459.73	458.0	38.20	28.40	9.8	419.80	429.60	NA		
LR-105	1067709.56	514524.56	486.79	484.2	36.00	26.20	9.8	448.20	458.00	NA		

Notes:
Survey data provided by Sherbut-Carson & Associates, P.C.
Horizontal Datum: Missouri State Plane Coordinate System
Vertical Datum: USGS North American Vertical Datum
All measurements provided in feet, except where indicated
PVC = Polyvinyl chloride casing, 2-inch ID Schedule 80
NA = Not applicable

Table 3-2. Piezometer and Leachate Riser Rationale, West Lake Landfill

PZ-100-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-100-SS is used in conjunction with PZ-115-SS and PZ-208-SS in triangulation of water levels along the northern end of the sanitary landfill.
PZ-100-SD	Boring completed in the lower portion of the Salem/St. Louis Formation. PZ-100-SD is used in conjunction with PZ-100-SS and PZ-100-KS to determine vertical gradients along the northern end of the sanitary landfill.
PZ-100-KS	Boring completed in the Keokuk Formation. This boring was continuously sampled during drilling and geophysically logged upon reaching total depth. PZ-100-KS is used in conjunction with PZ-100-SS and PZ-100-SD to determine vertical gradients along the northern end of the sanitary landfill.
PZ-101-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-101-SS is used in conjunction with PZ-102-SS and PZ-200-SS in triangulation of water levels along the northeastern portion of the sanitary landfill.
PZ-102-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. Bentonite was observed in purge water produced during development of PZ-102-SS, suggesting that the integrity of the piezometer was compromised. PZ-102-SS was replaced by PZ-102R-SS.
PZ-102R-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-102R-SS replaces PZ-102-SS. PZ-102R-SS is used in conjunction with PZ-101-SS and PZ-200-SS in triangulation of water levels along the eastern portion of the sanitary landfill.
PZ-103-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-103-SS is used in conjunction with PZ-201-SS and PZ-202-SS in triangulation of water levels along the eastern portion of the sanitary landfill.
PZ-104-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-104-SS is used in conjunction with PZ-105-SS and PZ-203-SS in triangulation of water levels along the southeastern portion of the sanitary landfill.
PZ-104-SD	Boring completed in the lower portion of the Salem/St. Louis Formation. PZ-104-SD is used in conjunction with PZ-104-SS and PZ-104-KS to determine vertical gradients along the southeastern edge of the sanitary landfill. This boring was geophysically logged from ground surface to top of Warsaw Formation.
PZ-104-KS	Boring completed into the Keokuk Formation. This boring was continuously sampled during drilling and geophysically logged from top of Warsaw Formation to total depth upon reaching total depth. PZ-104-KS is used in conjunction with PZ-104-SS and PZ-104-SD to determine vertical gradients along the southeastern end of the sanitary landfill.

Table 3-2. Piezometer and Leachate Riser Rationale (continued)

PZ-105-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-105-SS is used in conjunction with PZ-106-SS, PZ-204-SS, and LCS-2 in triangulation of water levels near the active landfill.
PZ-106-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-106-SS is used in conjunction with PZ-105-SS, PZ-204-SS, and LCS-2 in triangulation of water levels near the active landfill.
PZ-106-SD	Boring completed in the lower portion of the Salem/St. Louis Formation. PZ-106-SD is used in conjunction with PZ-106-SS and PZ-106KS to determine vertical gradients along the southeastern edge of the sanitary landfill.
PZ-106-KS	Boring completed into the Keokuk Formation. This boring was continuously sampled during drilling and geophysically logged upon reaching total depth. PZ-106-KS is used in conjunction with PZ-106-SS and PZ-106-SD to determine vertical gradients along the southern end of the sanitary landfill.
PZ-107-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-107-SS is used in conjunction with PZ-106-SS, LCS-4, and PZ-205-SS in triangulation of water levels near the southwestern corner of the sanitary landfill.
PZ-108-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-108-SS is used in conjunction with PZ-109-SS and PZ-206-SS in triangulation of water levels near the northwestern corner of the sanitary landfill.
PZ-109-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-109-SS is used in conjunction with PZ-108-SS and PZ-206-SS in triangulation of water levels near the old quarry.
PZ-110-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-110-SS assists in defining the location of the edge of the alluvial valley.
PZ-111-SD	Boring completed in the lower portion of the Salem/St. Louis Formation. PZ-111-SD is used in conjunction with MW-F1S, MW-F1D, and PZ-111-KS to determine vertical gradients along the western edge of the sanitary landfill.
PZ-111-KS	Boring completed into the Keokuk Formation. This boring was continuously sampled during drilling and geophysically logged upon reaching total depth. PZ-111-KS is used in conjunction with PZ-106-SD, MW-F1S, and MW-F1D to determine vertical gradients along the western edge of the sanitary landfill.
PZ-112-AS	Shallow boring completed in the alluvium. This boring was continuously sampled during drilling. This boring assists in determining the potentiometric surface between the inactive landfill to the west and the sanitary landfill to the east.

Table 3-2. Piezometer and Leachate Riser Rationale (continued)

PZ-113-AS	Shallow boring completed in the alluvium. PZ-113-AS is used in conjunction with PZ-207-AS ad S-84 in triangulation of water levels between the demolition landfill and the sanitary landfill.
PZ-113-AD	Boring completed at the base of the alluvium. PZ-113-AD is used in conjunction with PZ-113-AS to determine the vertical gradients between the demolition landfill and the sanitary landfill.
PZ-113-SS	Boring completed 50 feet into the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-113-SS is used in conjunction with PZ-113-AS and PZ-113-AD to determine vertical gradients between the demolition landfill and the sanitary landfill.
PZ-114-AS	Shallow boring completed in the alluvium. This boring was continuously sampled during drilling. PZ-114-AS is intended to provide potentiometric surface data north of the sanitary landfill.
PZ-115-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-115-SS is used in conjunction with PZ-100-SS and PZ-208-SS in triangulation of water levels along the northern end of the sanitary landfill.
PZ-116-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-116-SS is used in conjunction with PZ-105-SS and PZ-204A-SS in triangulation of water levels along the southern end of the sanitary landfill.
PZ-200-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-200-SS is used in conjunction with PZ-101-SS and PZ-102-SS in triangulation of water levels along the northeastern portion of the sanitary landfill. PZ-200-SS will also be used to determine landfill gas concentrations.
PZ-201-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-201-SS is used in conjunction with PZ-103-SS and PZ-202-SS in triangulation of water levels along the eastern portion of the sanitary landfill. PZ-201-SS will also be used to determine landfill gas concentrations.
PZ-201A-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-201A-SS is used to confirm groundwater level measurements in the adjacent PZ-201-SS.
PZ-202-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-202-SS is used in conjunction with PZ-103-SS in triangulation of water levels along the eastern portion of the sanitary landfill.
PZ-203-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-203-SS will be used in conjunction with PZ-104-SS and PZ-105-SS in triangulation of water levels along the southeastern portion of the sanitary landfill.

Table 3-2. Piezometer and Leachate Riser Rationale (continued)

PZ-204-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-204-SS is used in conjunction with PZ-105-SS, PZ-106-SS, and LCS-2 in triangulation of water levels near the active landfill. PZ-204-SS will also be used to determine landfill gas concentrations.
PZ-204A-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-204A-SS is used to confirm groundwater levels in the adjacent PZ-204-SS
PZ-205-AS	Shallow boring completed in the alluvium. PZ-205-AS is used in conjunction with PZ-205-SS to determine vertical gradients near the southwestern corner of the sanitary landfill.
PZ-205-SS	Deep boring completed 50 feet into the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-205-SS is used in conjunction with PZ-106-SS, PZ-107-SS, and LCS-4 in triangulation of water levels near the southwestern corner of the sanitary landfill.
PZ-206-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-206-SS is used in conjunction with PZ-108-SS and PZ-109-SS in triangulation of water levels near the northwestern corner of the sanitary landfill.
PZ-207-AS	Shallow boring completed in the alluvium. This boring was continuously sampled during drilling. PZ-207-AS is intended to define the hydrogeologic conditions between the demolition landfill and the sanitary landfill as well as to allow triangulation of water levels between the two landfills in conjunction with PZ-113-AS and S-84.
PZ-208-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-208-SS is used in conjunction with PZ-100-SS and PZ-115-SS in triangulation of water levels along the northern end of the sanitary landfill.
PZ-300-AS	Shallow boring completed in the alluvium. PZ-300-AS is intended to provide background groundwater quality data. The well was decommissioned in April 1996.
PZ-300-AD	Boring completed to the base of the alluvium and is intended to provide background groundwater quality data. PZ-300-AD was decommissioned in April 1996.
PZ-300-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-300-SS provided vertical gradient information between the alluvium and the bedrock in this groundwater setting. The well was decommissioned in April 1996.
PZ-301-SS	Shallow boring completed in the Salem/St. Louis Formation. The piezometer provides supplemental background data for the upper and lower Salem/St. Louis Formations, respectively.
PZ-302-AS	Shallow boring completed in the alluvium. PZ-302-AS is used in conjunction with PZ-302-AI to provide hydraulic head data immediately upgradient of the landfill materials.

Table 3-2. Piezometer and Leachate Riser Rationale (continued)

PZ-302-AI	Intermediate boring completed in the alluvium. PZ-302-AI is used in conjunction with PZ-300-AS to provide hydraulic head data immediately upgradient of the landfill materials.
PZ-303-AS	Shallow boring completed in the alluvium. PZ-303-AS is intended to provide information on the extent and magnitude of petroleum product impacts near monitoring well MW-F2.
PZ-304-AS	Shallow boring completed in the alluvium. PZ-304-AS is used in conjunction with PZ-304-AI to determine hydraulic head near the Earth City Stormwater retention feature, to compare water levels to leachate levels, and to determine vertical hydraulic gradients at the facility edge.
PZ-304-AI	Intermediate boring completed in the alluvium. PZ-304-AI is used in conjunction with PZ-304-AS to determine hydraulic head near the Earth City stormwater retention feature, to compare water levels to leachate levels, and to determine vertical gradients at the facility edge.
PZ-305-AI	Intermediate boring completed in the alluvium. PZ-305-AI was installed in the center of the site to allow triangulation across the western portion of the site.
LR-100	Shallow boring completed in inactive landfill waste. LR-100 is used to target potential source areas in the inactive landfill.
LR-101	Intermediate boring where no liquid was encountered. LR-101 is used to target potential source areas in the inactive landfill. Riser was not completed.
LR-102	Intermediate boring completed in inactive landfill waste. LR-102 is used to target potential source areas in the inactive landfill.
LR-103	Shallow boring completed in the alluvium. LR-103 was installed east of the inactive landfill to target two potential source areas.
LR-104	Shallow boring completed in the alluvium. LR-104 was installed east of the inactive landfill to target two potential source areas.
LR-105	Shallow boring completed in inactive landfill waste.

Table 3-3. Soil and Rock Classification System

<table>
<tr><td colspan="3">Major Divisions</td><td>Symbol</td><td>Desciption</td></tr>
<tr><td rowspan="8">Coarse Grained Soils (more than 50% larger than No. 200 Sieve Size)</td><td rowspan="4">Gravel and Gravelly Soils</td><td rowspan="2">Clean Gravels Little or no fines</td><td>GW</td><td>Well-Graded Gravel, Gravel-Sand Mixture</td></tr>
<tr><td>GP</td><td>Poorly-Graded Gravel, Gravel-Sand Mixture</td></tr>
<tr><td rowspan="2">Gravels with appreciable fines</td><td>GM</td><td>Silty Gravel, Gravel-Sand-Silt Mixture</td></tr>
<tr><td>GC</td><td>Clayey Gravel, Gravel-Sand-Clay Mixture</td></tr>
<tr><td rowspan="4">Sand and Sandy Soils</td><td rowspan="2">Clean Sand Little or no fines</td><td>SW</td><td>Well-Graded Sand, Gravelly Sand</td></tr>
<tr><td>SP</td><td>Poorly-Graded Sand, Gravelly Sand</td></tr>
<tr><td rowspan="2">Sands with appreciable fines</td><td>SM</td><td>Silty Sand, Sand-Silt Mixture</td></tr>
<tr><td>SC</td><td>Clayey Sand, Sand-Clay Mixture</td></tr>
<tr><td rowspan="7">Fine-Grained Soils (more than 50% smaller than No. 200 Sieve Size)</td><td rowspan="3">Silts and Clays</td><td rowspan="3">Liquid limit less than 50</td><td>ML</td><td>Silt, Clayey Silt, Silty or Clayey Very Fine Sand, Slight Plasticity</td></tr>
<tr><td>CL</td><td>Clay, Sandy Clay, Silty Clay, Low to Medium Plasticity</td></tr>
<tr><td>OL</td><td>Organic Silts or Silty Clays of Low Plasticity</td></tr>
<tr><td rowspan="3">Silts and Clays</td><td rowspan="3">Liquid limit more than 50</td><td>MH</td><td>Silt, Fine Sandy or Silty Soil with High Plasticity</td></tr>
<tr><td>CH</td><td>Clay, High Plasticity</td></tr>
<tr><td>OH</td><td>Organic Clay or Medium to High Plasticity</td></tr>
<tr><td colspan="2">Highly Organic Soils</td><td>PT</td><td>Peat, Humus, Swamp Soil</td></tr>
</table>

Angularity
Angular - Particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular - Particles are similar to angular description but have rounded edges.
Subrounded - Particles have nearly plane sides but have well-rounded corners and edges.
Rounded - Particles have smoothly curved sides and no edges.

Particle Shape
Flat - Particles with width/thickness x3
Elongated - Particles with length/width x3
Flat and Elongated - Particles meet criteria for both flat and elongated

Moisture Content
Dry - Absence of moisture, dusty, dry to the touch.
Moist - Damp but no visible water.
Wet - Visible free water, usually soil is below water table.

Table 3-3. Soil and Rock Classification System (continued)

Reaction with HCL
None - No visible reaction.
Weak - Some reaction, with bubbles forming slowly.
Strong - Violent reaction, with bubles forming immediately.

Cementation
Weak - Crumbles or breaks with handling or little finger pressure.
Moderate - Crumbles or breaks with considerable finger pressure.
Strong - Will not crumble or break with finger pressure.

Dry Strength
None - The dry specimen crumbles into powder with mere pressure of handling.
Low - The dry speciment crumbles into powder with some finger pressure.
Medium - The dry speciment breaks into pieces or crumbles with considerable finger pressure.
High - The dry speciment cannot be broken with finger pressure. Specimen will breakinto pieces between thumb and hard surface.
Very High - The dry specimen cannot be broken between the thumb and a hard surface.

Dilatancy
None - No visible change in the specimen.
Slow - Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid - Water appears quickly on the surface of the speciment during shaking and disappears quickly upon squeezing.

Toughness
Low - Only slight pressure is required to roll the thread near the plastic limit. The thread and lump are weak and soft.
Medium - Medium pressure is required to roll the thread near the plastic limit. The thread and lump have medium stiffness.
High - Considerable pressure is required to roll the thread near the plastic limit. The thread and the lump have very high stiffness.

Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	*Dry Strength*	*Dilatancy*	*Toughness*
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

Table 3-3. Soil and Rock Classification System (continued)

Rock Material Strength

Grade	Description	Field Identification	Approximate range of uniaxial Compressive strength (MPa)
S1	Very Soft Clay	Easily penetrated several inches fist	<0.025
S2	Soft Clay	Easily penetrated several inches by thumb.	0.025 to 0.05
S3	Firm Clay	Can be penetrated several inches by thumb with moderate effort.	0.05 to 0.10
S4	Stiff Clay	Readily indented by thumb, but penetrated only with great effort.	0.10 to 0.25
S5	Very Stiff Clay	Readily indented by thumbnail.	0.25 to 0.50
S6	Hard Clay	Indented with difficulty by thumbnail.	>0.50
R0	Extremely Weak Rock	Indented with thumbnail.	0.25 to 1.0
R1	Very Weak Rock	Crumbles under firm blows with point of geological hammer, can be penetrated by a pocket knife.	1.0 to 5.0
R2	Weak Rock	Can be peeled by a pocket knife with difficulty. Shallow indentions made by firm blow with point of geological hammer.	5.0 to 25
R3	Medium Strong Rock	Cannot be scrapped or peeled with a pocket knife. Specimen can be fractured with single firm blow of geological hammer.	25 to 50
R4	Strong Rock	Speciment requires more than one blow of geological hammer to fracture it.	50 to 100
R5	Very Strong Rock	Specimen requires many blows of geological hammer to fracture it.	100 to 250
R6	Extremely Strong Rock	Specimen can only be chipped with geological hammer.	>250

Weathered State

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces.	I
Slightly Weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.	II
Moderately Weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.	III
Highly Weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.	IV
Completely Weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
Residual Soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

Table 3-4. Summary of Soil Data, West Lake Landfill

Boring No.	Sample No.	Sample Depth (ft)	USCS Soil Classification	Natural Moisture	Atterburg Limits				Grain Size Distribution		Specific Gravity	Void Ratio	Unit of Weight of PCF		Additional Tests Comments (see notes)
					L.L.	P.L.	P.I.	S.L.	% Finer No. 4 Sieve	% Finer No. 200 Sieve			Wet	Dry	
PZ-100-KS	---	4-6, 6-8	CL	---	40	24	16	---	100	89	2.62	---	---	---	---
PZ-101-SS	---	4-6, 6-8	CL	24.4	38	22	16	---	100	92	2.68	---	---	---	Perm
PZ-102-SS	---	4-6, 8-10	CL-ML	28.2	39	25	14	---	100	99	2.69	---	---	---	Perm
PZ-102R-SS	---	12-14, 14-16	CL	---	34	24	10	---	100	96	2.76	---	---	---	---
PZ-102R-SS	---	18-20	---	---	---	---	---	---	100	8	2.69	---	---	---	---
PZ-102R-SS	---	28-30	---	---	---	NP	NP	---	---	---	---	---	---	---	---
PZ-103-SS	---	12-14, 14-16	ML	28.3	---	NP	NP	---	100	97	2.67	---	---	---	Perm
PZ-104-KS	---	4-6, 6-8	CL	23.6	46	25	21	---	100	94	2.66	---	---	---	Perm
PZ-105-SS	---	8-10, 10-12	CL	---	40	22	18	---	100	99	2.71	---	---	---	---
PZ-105-SS	---	18-20	---	---	---	NP	NP	---	---	---	---	---	---	---	---
PZ-105-SS	---	30-32	---	---	---	---	---	---	100	11	---	---	---	---	---
PZ-106-KS	---	6-8. 8-10	CL	22.2	47	20	27	---	100	79	2.77	---	---	---	Perm
PZ-106-KS	GTS-1	201.9-202.5	---	---	---	---	---	---	---	---	---	---	---	---	Perm
PZ-106-KS	GTS-2	229.6-230.1	---	---	---	---	---	---	---	---	---	---	---	---	Perm
PZ-107-SS	---	22-24	---	---	---	---	---	---	100	99	2.69	---	---	---	---
PZ-108-SS	---	16-18	---	---	---	---	---	---	100	65	2.77	---	---	---	---
PZ-109-AS	---	10-12	CL	28.1	44	19	25	---	100	82	2.61	---	---	---	---
PZ-110-SS	---	4-6	---	---	31	22	9	---	---	---	---	---	---	---	---
PZ-110-SS	---	52-54	---	---	---	---	---	---	100	11	2.67	---	---	---	---
PZ-112-AS	---	34-36	SP	14.0	---	---	---	---	99	3	---	---	---	---	---
PZ-113-AS	---	4-6	---	14.2	26	18	8	---	---	---	---	---	---	---	---
PZ-113-AS	---	6-8, 8-10	CL	---	35	16	19	---	99	73	2.69	---	---	---	---
PZ-113-AS	---	10-12	CL	20.1	32	23	9	---	100	83	2.62	---	---	---	---
PZ-113-AS	---	28-30	---	---	---	---	---	---	100	17	---	---	---	---	---
PZ-113-AS	---	34-36	SP-SM	18.0	---	---	---	---	100	7	---	---	---	---	---
PZ-113-AS	---	94-96	---	---	---	---	---	---	98	6	---	---	---	---	---
PZ-114-AS	---	12-14	CL	33.2	40	24	16	---	97	87	2.51	---	---	---	---
PZ-114-AS	---	24-26	---	20.3	---	---	---	---	100	28	---	---	---	---	---
PZ-115-SS	---	30-32	---	---	---	---	---	---	100	6	2.72	---	---	---	---
PZ-116-SS	---	7-9	---	---	34	23	11	---	---	---	---	---	---	---	---
PZ-116-SS	---	15-17	---	---	---	NP	NP	---	---	---	---	---	---	---	---
PZ-116-SS	---	29-31	---	---	---	---	---	---	100	2	---	---	---	---	---

Table 3-4. Summary of Soil Data (continued)

PZ-200-SS	---	6-8, 8-10	CL-ML	27.5	36	24	12	---	100	98	2.64	---	---	---	Perm
PZ-201-SS	---	24-26, 26-28	ML	34.5	---	NP	NP	---	100	89	2.62	---	---	---	Perm
PZ-202-SS	---	6-8, 8-10	CL	26.7	45	24	21	---	100	97	2.74	---	---	---	Perm
PZ-203-SS	---	2-4	---	---	32	21	11	---	---	---	---	---	---	---	---
PZ-203-SS	---	8-10, 10-12	ML	---	36	25	11	---	100	97	2.85	---	---	---	---
PZ-203-SS	---	38-40	---	---	---	---	---	---	100	13	---	---	---	---	---
PZ-204-SS	---	8-10, 10-12	ML	---	---	NP	NP	---	100	77	2.68	---	---	---	---
PZ-205-SS	---	28-30	---	---	---	---	---	---	100	90	2.64	---	---	---	---
PZ-205-AS	---	31-33	ML	---	---	NP	NP	---	99	79	2.68	---	---	---	---
PZ-205-AS	---	41-43, 43-45	ML	---	---	NP	NP	---	100	66	2.81	---	---	---	---
PZ-206-SS	---	8-10, 32-34	SP-SM	---	---	NP	NP	---	100	11	2.62	---	---	---	---
PZ-207-AS	---	36-38	SP	17.0	---	---	---	---	100	3	---	---	---	---	---
PZ-208-SS	---	2-4	---	---	40	18	22	---	---	---	---	---	---	---	---
PZ-208-SS	---	8-10, 10-12	CL	---	34	22	12	---	100	60	---	---	---	---	---
PS-1	---	-10	CL	23.0	47	17	30	---	100	99	2.74	---	---	---	P, Perm
PS-2	---	-7	CL	25.9	39	22	17	---	100	98	2.81	---	---	---	P, Perm
LR-103	---	20-22	CH	37.4	80	29	51	---	100	99	---	---	---	---	Perm

Notes:

LL = Liquid Limit
PL = Plastic Limit
PI = Plastic Index
SL = Shrinkage Limit

T = Triaxial Test
U = Unconfined Compression Test
C = Consolidation Test
P = Proctor Test
DS = Direct Shear Test
Perm = Permeability

Table 3-5. Summary of Flexible Wall Permeability Test Results, West Lake Landfill

Sample Number	Sample Length (cm)	Sample Diameter (cm)	Sample Dry Density (pcf)	Maximum Dry Density (pcf)	Compaction (%)	Initial Moisture Content (%)	Optimum Moisture Content (%)	Effective Pressure (psi)	Back Pressure (psi)	Gradient	Average Permeability (cm/sec)
PZ-101-SS 6-8	7.99	7.22	91.7	---	---	24.4	---	6	94	2	3×10^{-4}
PZ-102-SS 4-6	8.82	7.07	92.2	---	---	28.2	---	5	95	9	8×10^{-7}
PZ-103-SS 14-16	7.73	7.18	97.7	---	---	28.3	---	13	87	4	2×10^{-6}
PZ-104-KS 6-8	9.11	7.14	95.7	---	---	23.6	---	6	94	24	2×10^{-7}
PZ-106-KS 6-8	8.89	7.14	103.0	---	---	22.2	---	6	94	5	3×10^{-6}
PZ-106-KS GTS-1 201.9-202.5	7.63	4.50	151.9	---	---	4.5	---	153	98	129	$<1.1 \times 10^{-10}$
PZ-106-KS GTS-2 229.6-230.1	7.66	4.47	148.0	---	---	4.4	---	170	88	94	1.5×10^{-10}
PZ-200-SS 6-8	9.59	7.17	95.3	---	---	27.5	---	6	94	4	2×10^{-6}
PZ-201-SS 26-28	8.11	7.13	86.4	---	---	34.5	---	23	77	14	3×10^{-6}
PZ-202-SS 6-8	8.08	7.10	96.4	---	---	26.7	---	6	94	10	3×10^{-7}
PS-1 10	9.56	7.23	100.8	105.0	96	18.4	19.0	5	95	6	2×10^{-7}
PS-2 7	9.55	7.24	101.7	106.0	96	17.5	17.5	5	95	10	3×10^{-7}
LR-103	10.16	7.22	79.9	---	---	37.4	17.5	5	95	3	2×10^{-4}

Table 3-6. Summary of Packer Testing Results
Keokuk Formation - West Lake Landfill

Borehole	Ground Surface Elevation	Keokuk Test Interval (depth below ground surface)	Hydraulic Conductivity	
			cm/sec	ft/min
PZ-100-KS	438.3	366.0-391.0	7.6E-7	1.5E-6
		377.0-391.0	1.4E-6	2.7E-6
PZ-104-KS	482.3	366.0-371.0	4.0E-6	7.9E-6
		360.0-408.0	5.7E-6	1.1E-5
		390.0-408.0	1.3E-5	2.6E-5
PZ-106-KS	460.8	357.0-362.2	2.8E-5	5.5E-5
		346.0-374.1	2.2E-5	4.3E-5
		364.0-374.0	1.7E-5	3.4E-5
PZ-111-KS	459.2	343.0-348.0	2.5E-5	4.9E-5
		355.0-360.0	4.3E-5	8.5E-5
		343.0-368.0	2.1E-5	4.1E-5
Geometric Mean			**9.7E-6**	**1.9E-5**

Table 3-7. Summary of Packer Testing Results
Warsaw Formation - West Lake Landfill

Borehole	Ground Surface Elevation	Keokuk Test Interval (depth below ground surface)	Hydraulic Conductivity	
			cm/sec	ft/min
PZ-100-KS	438.3	290.0-295.0	5.6E05	1.1E-4
		265.0-357.6	5.3E-6	1.0E-5
PZ-104-KS	482.3	287.0-292.5	2.7E-6	5.3E-6
		343.0-348.0	1.9E-6	3.7E-6
		270.0-290.0	4.4E-6	8.7E-7
		290.0-320.0	7.1E-7	1.4E-6
		320.0-358.3	3.4E-6	6.6E-7
PZ-106-KS	460.8	215.0-220.0	2.6E-7	5.1E-7
		237.0-242.0	2.4E-6	4.8E-6
		301.0-346.4	3.3E-5	6.6E-5
PZ-111-KS	459.2	221.0-226.0	9.5E-7	1.9E-6
		226.0-231.0	1.7E-6	3.3E-6
		260.0-265.0	2.0E-6	3.8E-6
		220.0-260.0	1.3E-6	2.5E-6
		260.0-290.0	1.1E-6	2.2E-6
		290.0-343.7	3.1E-6	6.1E-6
Geometric Mean			**2.6E-6**	**3.8E-6**

Table 3-8. Summary of Packer Testing Results
Salem Formation - West Lake Landfill

Borehole	Ground Surface Elevation	Keokuk Test Interval (depth below ground surface)	Hydraulic Conductivity	
			cm/sec	ft/min
PZ-100-KS	438.3	195.0-200.0	3.9E-6	7.7E-6
		220.0-225.0	2.1E-6	4.1E-6
PZ-104-KS	482.3	208.0-213.0	8.4E-6	1.7E-5
		162.0-252.5	4.9E-6	9.7E-6
		235.0-252.5	3.2E-7	6.4E-7
PZ-106-KS	460.8	148.0-153.0	4.5E-6	8.8E-6
		140.0-201.0	2.5E-5	5.0E-5
		187.0-201.0	1.8E-7	3.5E-7
PZ-111-KS	459.2	127.0-210.0	1.3E-6	2.6E-6
		162.0-167.0	7.9E-7	1.5E-6
		195.0-200.0	5.8E-8	1.1E-7
		140.0-210.0	3.3E-6	6.4E-6
		175.0-210.0	1.2E-6	2.4E-6
Geometric Mean			**1.6E-6**	**3.2E-6**

Table 3-9. Summary of Packer Testing Results
Saint Louis Formation - West Lake Landfill

Borehole	Ground Surface Elevation	Keokuk Test Interval (depth below ground surface)	Hydraulic Conductivity		Comments
			cm/sec	ft/min	
PZ-100-KS	438.3	37.3-42.3	7.5E-4	1.5E-3	Unsaturated
		50.0-55.0	3.3E-6	6.6E-6	Unsaturated
		110.0-115.0	3.7E-7	7.2E-7	Saturated
PZ-104-KS	482.3	50.0-55.0	2.9E-6	5.7E-6	Unsaturated
		113.0-118.0	1.5E-7	2.9E-7	Unsaturated
PZ-106-KS	460.8	42.0-47.0	6.0E-6	1.2E-5	Unsaturated
		61.0-66.0	2.1E-6	4.1E-6	Unsaturated
PZ-111-KS	459.2	125.0-130.0	5.4E-7	1.1E-6	Saturated
		105.0-127.0	4.4E-6	8.6E-6	Saturated
Geometric Mean			**4.9E-6**	**9.6E-6**	**Unsaturated**
			1.6E-6	**3.2E-6**	**Saturated**

Table 3-10. Summary of Slug Test Results, West Lake Landfill

Piezometer	Hydraulic Conductivity							
	Hvorslev		Bouwer & Rice		Cooper Papadopulos Best Fit		Mean Value of Hvorslev & Bouwer and Rice	
	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min
Shallow Alluvial Piezometers								
PZ-112-AS-RH1	1.9E-03	3.7E-03	1.1E-03	2.2E-03	NA	NA	1.5E-03	3.0E-03
PZ-112-AS-FH1	3.0E-03	5.9E-03	1.7E-03	3.3E-03	NA	NA	2.4E-03	4.6E-03
PZ-113-AS-RH1	1.4E-02	2.8E-02	5.3E-02	1.0E-01	NA	NA	3.4E-02	6.6E-02
PZ-113-AS-FH1	8.0E-03	1.6E-02	5.1E-03	1.0E-02	NA	NA	6.6E-03	1.3E-02
PZ-114-AS-FH1	3.1E-03	6.1E-03	1.7E-03	3.3E-03	NA	NA	2.4E-03	4.7E-03
PZ-114-AS-FH2	4.5E-03	8.9E-03	2.7E-03	5.3E-03	NA	NA	3.6E-03	7.1E-03
PZ-205-AS	6.0E-04	1.2E-03	4.4E-04	8.7E-04	NA	NA	5.2E-04	1.0E-03
PZ-207-AS	7.6E-03	1.5E-02	4.8E-03	9.4E-03	NA	NA	6.2E-03	1.2E-02
PZ-300-AS-FH[2]	5.8E-04	1.1E-03	NA	NA	NA	NA	5.8E-04	1.1E-03
PZ-300-AS-RH	7.1E-04	1.4E-03	2.1E-03	4.1E-03	NA	NA	1.4E-03	2.8E-03
PZ-302-AS-FH[2]	1.1E-04	2.2E-04	NA	NA	NA	NA	1.1E-04	2.2E-04
PZ-302-AS-RH	1.2E-04	2.4E-04	NA	NA	NA	NA	1.2E-04	2.4E-04
PZ-303-AS-FH1[2]	4.0E-04	7.9E-04	NA	NA	NA	NA	4.0E-04	7.9E-04
PZ-303-AS-FH2[2]	6.0E-04	1.2E-03	NA	NA	NA	NA	6.0E-04	1.2E-03
PZ-303-AS-RH	3.7E-03	7.3E-03	1.5E-02	3.0E-02	NA	NA	9.4E-03	1.8E-02
PZ-304-AS-FH[2]	8.7E-04	1.7E-03	NA	NA	NA	NA	8.7E-04	1.7E-03
PZ-304-AS-RH	5.9E-03	1.2E-02	1.8E-02	3.5E-02	NA	NA	1.2E-02	2.4E-02
Geometric Mean	**2.5E-03**	**5.0E-03**	**3.9E-03**	**7.6E-03**	**NA**	**NA**	**2.9E-03**	**5.8E-03**
Intermediate Alluvial Piezometers								
PZ-302-AI-FH	1.5E-02	3.0E-02	9.8E-03	1.9E-02	NA	NA	1.2E-02	2.4E-02
PZ-302-AI-RH	1.5E-02	3.0E-02	1.0E-02	2.0E-02	NA	NA	1.3E-02	2.5E-02
PZ-304-AI-FH	2.4E-02	4.7E-02	1.7E-02	3.3E-02	NA	NA	2.1E-02	4.0E-02
PZ-305-AI-FH[1]	1.8E-02	3.5E-02	1.4E-02	2.8E-02	NA	NA	1.6E-02	3.1E-02
PZ-305-AI-FH[2]	1.9E-04	3.7E-04	1.7E-04	3.3E-04	NA	NA	1.8E-04	3.5E-04
Geometric Mean	**1.8E-02**	**3.5E-02**	**1.2E-02**	**2.3E-02**	**NA**	**NA**	**1.5E-02**	**2.9E-02**
Deep Alluvial Piezometers								
PZ-113-AD-FH1	1.8E-03	3.5E-03	1.5E-03	3.0E-03	NA	NA	1.7E-03	3.2E-03
PZ-113-AD-FH2	1.9E-03	3.7E-03	1.4E-03	2.8E-03	NA	NA	1.7E-03	3.2E-03
PZ-300-AD-FH	3.7E-04	7.3E-04	2.7E-04	5.3E-04	NA	NA	3.2E-04	6.3E-04
PZ-300-AD-RH	1.6E-04	3.1E-04	1.1E-04	2.2E-04	NA	NA	1.4E-04	2.7E-04
Geometric Mean	**6.7E-04**	**1.3E-03**	**5.0E-04**	**9.8E-04**	**NA**	**NA**	**5.9E-04**	**1.2E-03**

Table 3-10. Summary of Slug Test Results, West Lake Landfill (continued)

Piezometer	Hydraulic Conductivity							
	Hvorslev		Bouwer & Rice		Cooper Papadopulos Best Fit		Mean Value of Hvorslev & Bouwer and Rice	
	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min
Shallow St. Louis/Salem Piezometers								
PZ-100-SS	1.0E-07	2.0E-07	5.7E-08	1.1E-07	NA	NA	7.9E-08	1.5E-07
PZ-101-SS	8.6E-07	1.7E-06	5.1E-07	1.0E-06	NA	NA	6.9E-07	1.3E-06
PZ-102R-SS	4.7E-08	9.3E-08	3.0E-08	5.9E-08	NA	NA	3.9E-08	7.6E-08
PZ-103-SS	8.4E-07	1.7E-06	1.7E-06	3.3E-06	NA	NA	1.3E-06	2.5E-06
PZ-104-SS	6.0E-07	1.2E-06	1.3E-06	2.6E-06	NA	NA	9.5E-07	1.9E-06
PZ-105-SS	3.5E-06	6.9E-06	8.5E-06	1.7E-05	NA	NA	6.0E-06	1.2E-05
PZ-106-SS	3.9E-06	7.7E-06	2.5E-06	4.9E-06	NA	NA	3.2E-06	6.3E-06
PZ-107-SS	1.6E-06	3.1E-06	1.2E-06	2.4E-06	NA	NA	1.4E-06	2.8E-06
PZ-108-SS	6.3E-07	1.2E-06	4.3E-07	8.5E-07	NA	NA	5.3E-07	1.0E-06
PZ-109-SS	1.8E-07	3.5E-07	8.7E-08	1.7E-07	NA	NA	1.3E-07	2.6E-07
PZ-110-SS[1]	1.6E-06	3.1E-06	8.9E-07	1.8E-06	NA	NA	1.2E-06	2.5E-06
PZ-113-SS	5.2E-06	1.0E-05	4.9E-06	9.6E-06	NA	NA	5.1E-06	9.9E-06
PZ-115-SS	2.9E-05	5.7E-05	2.4E-05	4.7E-05	NA	NA	2.7E-05	5.2E-0-5
PZ-116-SS	2.9E-08	5.7E-08	1.7E-08	3.3E-08	NA	NA	2.3E-08	4.5E-08
PZ-200-SS	1.5E-06	3.0E-06	2.8E-06	5.5E-06	NA	NA	2.2E-06	4.2E-06
PZ-201-SS	3.3E-05	6.5E-05	5.4E-05	1.1E-04	NA	NA	4.4E-05	8.6E-05
PZ-201A-SS	1.3E-07	2.6E-07	8.3E-08	1.6E-07	NA	NA	1.1E-07	2.1E-07
PZ-202-SS	3.0E-03	5.9E-03	2.5E-03	4.9E-03	NA	NA	2.8E-03	5.4E-03
PZ-204-SS	1.8E-06	3.5E-06	2.8E-06	5.5E-06	NA	NA	2.3E-06	4.5E-06
PZ-204A-SS	3.5E-07	6.9E-07	2.3E-07	4.5E-07	NA	NA	2.9E-07	5.7E-07
PZ-205-SS	4.4E-07	8.7E-07	3.9E-07	7.7E-07	NA	NA	4.2E-07	8.2E-07
PZ-206-SS	1.8E-05	3.5E-05	1.1E-05	2.2E-05	NA	NA	1.5E-05	2.9E-05
PZ-208-SS	4.3E-07	8.5E-07	2.7E-07	5.3E-07	NA	NA	3.5E-07	6.9E-07
PZ-300-SS	9.0E-07	1.8E-06	7.7E-07	1.5E-06	NA	NA	8.4E-07	1.6E-06
PZ-301-SS[1]	7.5E-07	1.5E-06	NA	NA	NA	NA	7.5E-07	1.5E-06
Geometric Mean	**1.3E-06**	**2.6E-06**	**1.2E-06**	**2.4E-06**	**NA**	**NA**	**1.3E-06**	**2.6E-06**

Table 3-10. Summary of Slug Test Results, West Lake Landfill (continued)

Piezometer	Hydraulic Conductivity							
	Hvorslev		Bouwer & Rice		Cooper Papadopulos Best Fit		Mean Value of Hvorslev & Bouwer and Rice	
	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min
Deep Salem Piezometers								
PZ-100-SD	9.1E-07	1.8E-06	6.4E-07	1.3E-06	NA	NA	7.8E-07	1.5E-06
PZ-104-SD	1.8E-05	3.5E-05	1.2E-05	2.3E-05	NA	NA	1.5E-05	2.9E-05
PZ-106-SD	3.0E-07	5.9E-07	1.6E-07	3.1E-07	NA	NA	2.3E-07	4.5E-07
PZ-111-SD	1.0E-07	2.0E-07	6.8E-08	1.3E-07	NA	NA	8.4E-08	1.7E-07
Geometric Mean	**8.4E-07**	**1.6E-06**	**5.4E-07**	**1.1E-06**	**NA**	**NA**	**6.9E-07**	**1.4E-06**
Keokuk Piezometers								
PZ-100-KS	NA	NA	NA	NA	6.0E-07	1.2E-06	NA	NA
PZ-104-KS	NA	NA	NA	NA	2.5E-06	4.9E-06	NA	NA
PZ-106-KS	NA	NA	NA	NA	3.1E-06	6.1E-06	NA	NA
PZ-111-KS	NA	NA	NA	NA	3.8E-06	7.5E-06	NA	NA
Geometric Mean	**NA**	**NA**	**NA**	**NA**	**2.1E-06**	**4.0E-06**	**NA**	**NA**

Notes:
cm/sec = centimeters per second
ft/min = feet per minute

NA = Not Applicable. These analyses were not performed and/or were inapplicable for data from these boreholes.

[1] Slug tests conducted before piezometer reached equilibrium; data presented but not included in geometric means.

[2] Falling head slug tests conducted within sand pack zone of well; data presented but not included in geometric means.

Table 3-11. Water Level Elevation Summary, West Lake Landfill

Monitoring Location	June 27, 1995	July 26, 1995	Aug. 26, 1995	Sept. 30, 1995	Nov. 18, 1995	Dec. 14, 1995	Jan. 4, 1996
	Date						
	Groundwater Elevation						
Shallow Alluvial Piezometers							
PZ-112-AS	436.12	435.12	434.67	432.84	431.84	431.15	431.05
PZ-113-AS	435.62	435.30	434.63	432.91	431.81	431.18	431.07
PZ-114-AS	435.94	435.35	434.90	433.06	431.93	431.23	431.20
PZ-205-AS	434.41	434.33	434.06	432.52	431.66	431.19	430.98
PZ-207-AS	435.94	435.41	434.91	433.02	431.87	431.19	431.10
PZ-300-AS	NA	NA	NA	NA	435.50	434.94	434.11
PZ-302-AS	NA	NA	NA	NA	432.08	431.86	431.34
PZ-303-AS	NA	NA	NA	NA	432.01	431.74	431.28
PZ-304-AS	NA	NA	NA	NA	431.91	431.63	431.13
Intermediate Alluvial Piezometers							
PZ-302-AI	NA	NA	NA	NA	432.00	431.73	431.27
PZ-304-AI	NA	NA	NA	NA	431.98	431.66	431.16
PZ-305-AI	NA	NA	NA	NA	431.80	431.34	431.03
Deep Alluvial Piezometers							
PZ-113-AD	435.68	435.13	433.74	432.89	431.82	431.18	431.03
PZ-300-AD	NA	NA	NA	NA	432.78	432.41	432.12
St. Louis/Upper Salem Hydrologic Unit Piezometers							
PZ-100-SS	405.36	416.06	415.23	414.35	413.85	413.68	413.63
PZ-101-SS	393.23	394.58	393.37	390.00	387.58	386.76	387.48
PZ-102-SS	413.54	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
PZ-102R-SS	403.09	424.30	424.87	422.80	421.63	420.78	420.59
PZ-103-SS	363.03	373.02	363.73	360.95	361.05	360.15	361.47
PZ-104-SS	340.67	360.04	366.22	361.01	360.41	360.55	361.53
PZ-105-SS	336.26	339.83	352.45	346.80	342.76	342.53	343.21
PZ-106-SS	359.72	357.60	364.20	349.41	350.01	342.64	343.70
PZ-107-SS	434.52	434.30	434.00	432.36	431.57	431.12	430.90
PZ-108-SS	368.99	368.99	367.02	352.14	356.78	347.44	346.47
PZ-109-SS	370.70	373.74	360.45	359.20	355.12	351.80	350.40
PZ-110-SS	413.76	433.53	433.27	431.57	430.58	430.11	429.87
PZ-113-SS	435.70	435.23	434.79	433.00	431.94	427.33	431.16
PZ-115-SS	426.75	424.83	424.18	417.06	411.71	407.86	414.34

Table 3-11. Water Level Elevation Summary, West Lake Landfill (continued)

Monitoring Location	June 27, 1995	July 26, 1995	Aug. 26, 1995	Sept. 30, 1995	Nov. 18, 1995	Dec. 14, 1995	Jan. 4, 1996
	Groundwater Elevation						
PZ-116-SS	NA	346.79	356.46	338.17	331.43	330.07	330.68
PZ-200-SS	415.05	415.45	415.59	414.38	412.78	412.91	412.73
PZ-201-SS	456.42	455.53	454.86	453.55	452.98	452.80	452.45
PZ-201A-SS	415.03	414.63	414.38	412.94	412.57	412.12	412.13
PZ-202-SS	444.36	444.78	444.14	441.33	439.70	439.13	438.64
PZ-203-SS	(Dry)	(Dry)	(Dry)	(Dry)	(Dry)	(Dry)	(Dry)
PZ-204-SS	442.82	441.49	438.10	431.82	430.57	429.71	431.58
PZ-204A-SS	NA	405.65	405.53	404.05	403.55	403.45	403.78
PZ-205-SS	424.46	424.04	423.45	421.75	421.28	420.50	420.28
PZ-206-SS	420.04	419.04	418.22	415.49	415.19	NA	414.13
PZ-208-SS	NA	436.44	435.60	431.63	428.83	426.97	428.60
PZ-300-SS	NA	NA	NA	NA	428.32	427.80	427.50
PZ-301-SS	NA	NA	NA	NA	357.19	384.19	395.65
PZ-1201-SS	NA	392.33	365.30	377.98	374.88	374.88	376.00
MW-1206	368.19	367.12	367.86	351.67	362.46	348.15	348.17
Deep Salem Piezometers							
PZ-100-SD	394.61	370.68	381.79	366.35	364.43	356.68	355.04
PZ-104-SD	359.05	356.64	362.97	344.33	341.90	339.05	343.15
PZ-106-SD	358.64	353.52	361.98	348.44	347.38	340.60	341.52
PZ-111-SD	373.70	423.87	428.55	432.22	431.47	430.93	430.63
MW-1204	333.83	330.01	357.27	305.57	303.18	309.24	306.96
MW-1205	352.28	357.38	296.81	341.10	317.88	337.07	339.32
Keokuk Piezometers							
PZ-100-KS	438.17	438.93	437.84	434.72	433.67	432.84	432.69
PZ-104-KS	444.63	444.74	444.27	441.98	440.77	440.42	440.22
PZ-106-KS	442.18	442.51	442.48	440.30	439.02	438.82	438.61
PZ-111-KS	441.58	441.91	442.01	440.39	439.14	438.85	438.77

Notes:
NA = Not available. Water level data was not collected on the indicated date because the piezometer had not yet been installed, or development was not yet completed. An equipment malfunction prevented measurement of the water level in PZ-206-SS on December 14, 1995.

PZ-102-SS was replaced by PZ-102R-SS and is inactive.
All elevations provided in feet above Mean Sea Level (MSL).

Table 3-11. Water Level Elevation Summary, West Lake Landfill (continued)

Monitoring Location	June 27, 1995	July 26, 1995	Aug. 26, 1995	Sept. 30, 1995	Nov. 18, 1995	Dec. 14, 1995	Jan. 4, 1996
	Lechate Elevation						
Leachate Risers							
LR-100	NA	NA	NA	NA	450.42	449.90	449.77
LR-102	NA	NA	NA	NA	452.38	452.31	452.28
LR-103	NA	NA	NA	NA	431.86	431.32	431.00
LR-104	NA	NA	NA	NA	432.20	431.35	431.01
LR-105	NA	NA	NA	NA	452.44	452.38	453.39
	Surface Water Elevation						
Staff Gauges							
SG-8	NA	NA	NA	NA	433.54	432.75	433.68
SG-9	NA	NA	NA	NA	433.54	432.75	433.68

Notes:
NA = Not available. Water level data was not collected on the indicated date either because the leachate riser or staff gauges had not yet been installed, or development was not yet completed.

LR-101 was not installed because leachate was not present.

Table 3-11. Water Level Elevation Summary, West Lake Landfill (continued)

Monitoring Location	Feb. 6, 1996	Mar. 4, 1996	Apr. 3, 1996	May 3, 1996	June 13, 1996	July 12, 1996	May 22, 2000
	Groundwater Elevation						
Shallow Alluvial Piezometers							
PZ-112-AS	460.46	429.80	429.53	430.43	434.63	434.31	429.08
PZ-113-AS	430.47	429.93	429.48	430.79	432.74	434.39	428.67
PZ-114-AS	430.67	430.09	429.93	431.60	435.18	434.46	428.86
PZ-205-AS	430.54	431.04	429.85	430.68	433.79	433.71	429.05
PZ-207-AS	430.52	429.97	429.66	431.12	434.99	434.52	428.71
PZ-300-AS	434.03	433.72	434.02	****	****	****	****
PZ-302-AS	430.80	430.27	430.03	431.26	434.63	434.12	428.77
PZ-303-AS	430.64	430.03	429.77	430.99	434.37	434.23	428.92
PZ-304-AS	430.52	429.93	429.59	431.07	434.44	434.14	428.87
Intermediate Alluvial Piezometers							
PZ-302-AI	430.66	430.08	426.75	431.10	434.36	434.05	428.93
PZ-304-AI	430.57	429.96	429.62	431.13	434.48	434.20	428.92
PZ-305-AI	430.56	429.93	429.79	430.65	434.36	434.17	428.79
Deep Alluvial Piezometers							
PZ-113-AD	430.44	429.92	429.62	430.81	434.79	434.35	428.65
PZ-300-AD	431.44	430.73	430.63	****	****	****	****
St. Louis/Upper Salem Hydrologic Unit Piezometers							
PZ-100-SS	413.46	413.20	412.87	412.83	413.10	412.94	425.55
PZ-101-SS	385.28	385.58	385.24	385.09	377.47	387.08	418.16
PZ-102-SS	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
PZ-102R-SS	404.70	404.61	418.91	418.24	419.58	420.60	437.30
PZ-103-SS	362.30	362.01	362.85	363.71	364.44	363.42	416.77
PZ-104-SS	365.31	362.92	362.99	376.44	376.30	371.10	411.78
PZ-105-SS	357.72	350.46	356.22	376.83	376.59	370.61	410.92
PZ-106-SS	359.94	347.42	357.55	371.56	375.01	368.46	406.03
PZ-107-SS	430.24	429.58	429.35	430.34	433.79	433.55	428.59
PZ-108-SS	351.88	346.25	356.00	359.97	361.50	358.19	404.48
PZ-109-SS	350.84	350.87	350.78	352.41	358.18	360.57	406.71
PZ-110-SS	429.09	428.31	427.51	428.65	432.45	432.09	425.12
PZ-113-SS	430.58	430.06	429.65	430.89	434.81	434.46	428.42
PZ-115-SS	413.23	406.34	414.31	423.51	425.80	421.85	426.24

Table 3-11. Water Level Elevation Summary, West Lake Landfill (continued)

Monitoring Location	Feb. 6, 1996	Mar. 4, 1996	Apr. 3, 1996	May 3, 1996	June 13, 1996	July 12, 1996	May 22. 2000
	Groundwater Elevation						
PZ-116-SS	351.62	346.13	337.96	353.41	364.27	365.51	396.09
PZ-200-SS	412.42	412.14	412.03	412.05	412.36	412.28	431.34
PZ-201-SS	452.24	452.21	451.88	451.69	452.34	453.27	457.40
PZ-201A-SS	411.92	411.92	412.06	412.03	412.58	413.08	430.09
PZ-202-SS	441.28	440.27	441.20	441.81	446.98	447.77	455.96
PZ-203-SS	(Dry)	(Dry)	(Dry)	377.56	379.04	375.52	414.11
PZ-204-SS	440.83	439.74	440.02	441.19	441.45	440.23	447.69
PZ-204A-SS	405.38	405.15	405.46	406.69	406.07	405.53	413.86
PZ-205-SS	419.93	419.10	419.11	420.13	423.25	422.97	424.45
PZ-206-SS	413.86	413.53	413.80	414.81	419.31	418.89	425.00
PZ-208-SS	428.93	426.41	428.87	432.54	434.82	434.73	443.01
PZ-300-SS	427.88	426.56	426.58	****	****	****	****
PZ-301-SS	407.66	415.13	420.17	423.94	427.35	428.76	NM
PZ-1201-SS	378.52	372.92	379.44	NM	378.82	380.34	420.00
MW-1206	359.29	350.53	359.27	****	****	****	****
Deep Salem Piezometers							
PZ-100-SD	363.01	357.73	372.88	367.82	375.93	367.04	427.95
PZ-104-SD	361.88	348.24	360.25	370.88	376.92	367.77	412.80
PZ-106-SD	356.82	346.26	350.17	364.81	369.43	367.31	405.42
PZ-111-SD	430.06	429.43	428.90	429.00	432.55	433.46	428.31
MW-1204	356.52	318.98	332.51	344.32	360.30	332.89	*
MW-1205	350.89	314.15	342.90	****	****	****	****
Keokuk Piezometers							
PZ-100-KS	435.10	433.96	435.71	435.56	438.84	439.35	450.34
PZ-104-KS	443.10	441.74	442.94	443.35	447.35	447.40	455.78
PZ-106-KS	440.70	439.91	440.50	440.68	442.63	444.46	452.31
PZ-111-KS	440.04	439.92	440.13	440.16	442.55	443.66	450.62

Notes:
NA = Not available. Water level data was not collected on the indicated date because the piezometer had not yet been installed, or development was not yet completed.
* = Obstruction in well
**** = Wells decommissioned in May, 1996.
PZ-102-SS was replaced by PZ-102R-SS and is inactive.
All elevations provided in feet above Mean Sea Level (MSL).

Table 3-11. Water Level Elevation Summary, West Lake Landfill (continued)

Monitoring Location	Feb. 6, 1996	Mar. 4, 1996	Apr. 3, 1996	May 3, 1996	June 13, 1996	July 12, 1996	May 22, 2000
			Lechate Elevation				
Leachate Risers							
LR-100	450.14	450.60	450.61	451.64	452.02	451.71	450.89
LR-102	452.18	452.22	452.51	452.30	454.20	453.82	453.79
LR-103	430.58	429.98	429.71	430.75	434.49	434.25	434.19
LR-104	430.56	429.95	429.82	430.59	434.37	434.15	428.79
LR-105	453.40	453.61	453.70	453.43	453.61	453.71	453.58
			Surface Water Elevation				
Staff Gauges							
SG-8	433.98	(Dry)	433.99	433.07	433.86	433.87	**
SG-9	433.98	(Dry)	433.97	433.02	433.86	433.87	**

Notes:
NA = Not available. Water level data was not collected on the indicated date either because the leachate riser or staff gauges had not yet been installed, or development was not yet completed.
** = SG-8 and SG-9 were apparently destroyed prior to May 2000
LR-101 was not installed because leachate was not present.

Table 3-12. Vertical Hydraulic Gradient - October 28, 1995
West Lake Landfill

Interval Monitored	Piezometer Pair	Δ H	Δ L	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS / PZ-302-AI	432.34-432.16	432.40-412.50	0.009
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS / PZ-304-AI	432.19-432.19	429.40-407.70	0
Shallow Alluvium to Deep Alluvium	PZ-113-AS / PZ-113-AD	432.19-432.28	425.92-356.36	-0.0013
Shallow Alluvium to Deep Alluvium	PZ-300-AS / PZ-300-AD	436.41-432.89	433.70-408.60	0.14
Shallow Alluvium to St. Louis/Salem	PZ-114-AS / PZ-115-SS	432.11-413.09	424.78-370.03	0.34
Shallow Alluvium to St. Louis/Salem	PZ-205-AS / PZ-205-SS	431.90-421.69	416.88-367.56	0.21
Deep Alluvium to St. Louis/Salem	PZ-113-AD / PZ-113-SS	432.28-432.29	356.36-306.36	-0.0002
Deep Alluvium to St. Louis/Salem	PZ-300-AD / PZ-300-SS	432.89-428.62	408.60-359.61	0.09
St. Louis/Salem to Deep Salem	PZ-100-SS / PZ-100-SD	414.04-363.78	400.57-244.65	0.32
St. Louis/Salem to Deep Salem	PZ-104-SS / PZ-104-SD	360.34-341.68	342.16-241.25	0.18
St. Louis/Salem to Deep Salem	PZ-106-SS / PZ-106-SD	350.41-346.40	300.75-265.75	0.11
Deep Salem to Keokuk	PZ-100-SD / PZ-100-KS	363.78-433.90	244.65-104.86	-0.50
Deep Salem to Keokuk	PZ-104-SD / PZ-104-KS	341.68-440.99	241.25-80.05	-0.62
Deep Salem to Keokuk	PZ-106-SD / PZ-106-KS	346.40-439.47	265.75-93.07	-0.53
Deep Salem to Keokuk	PZ-111-SD / PZ-111-KS	431.90-439.68	254.92-97.18	-0.05

Δ H = Head differential
Δ L = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the contect of this table to represent an upward gradient (i_v).
Thus, a positive value represent a downward gradient.

Table 3-13. Vertical Hydraulic Gradient - January 4, 1996
West Lake Landfill

Interval Monitored	Piezometer Pair	Δ H	Δ L	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS / PZ-302-AI	431.34-431.27	432.40-412.50	0.004
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS / PZ-304-AI	431.13-431.16	429.40-407.70	-0.008
Shallow Alluvium to Deep Alluvium	PZ-113-AS / PZ-113-AD	431.07-431.03	425.92-356.36	0.006
Shallow Alluvium to Deep Alluvium	PZ-300-AS / PZ-300-AD	434.11-432.12	433.70-408.60	0.08
Shallow Alluvium to St. Louis/Salem	PZ-114-AS / PZ-115-SS	431.20-414.34	424.78-370.03	0.31
Shallow Alluvium to St. Louis/Salem	PZ-205-AS / PZ-205-SS	430.98-420.28	416.88-367.56	0.22
Deep Alluvium to St. Louis/Salem	PZ-113-AD / PZ-113-SS	431.03-431.16	356.36-306.36	-0.003
Deep Alluvium to St. Louis/Salem	PZ-300-AD / PZ-300-SS	432.12-427.50	408.60-359.61	0.09
St. Louis/Salem to Deep Salem	PZ-100-SS / PZ-100-SD	413.63-355.04	400.57-244.65	0.38
St. Louis/Salem to Deep Salem	PZ-104-SS / PZ-104-SD	361.53-343.15	342.16-241.25	0.18
St. Louis/Salem to Deep Salem	PZ-106-SS / PZ-106-SD	343.70-341.52	300.75-265.75	0.06
Deep Salem to Keokuk	PZ-100-SD / PZ-100-KS	355.04-432.69	244.65-104.86	-0.56
Deep Salem to Keokuk	PZ-104-SD / PZ-104-KS	343.15-440.22	241.25-80.05	-0.6
Deep Salem to Keokuk	PZ-106-SD / PZ-106-KS	341.52-438.61	265.75-93.07	-0.56
Deep Salem to Keokuk	PZ-111-SD / PZ-111-KS	430.63-438.77	254.92-97.18	-0.05

Δ H = Head differential
Δ L = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the contect of this table to represent an upward gradient (i_v). Thus, a positive value represent a downward gradient.

Table 3-14. Vertical Hydraulic Gradient - April 3, 1996
West Lake Landfill

Interval Monitored	Piezometer Pair	Δ H	Δ L	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS / PZ-302-AI	430.03-426.75	432.40-412.50	0.16
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS / PZ-304-AI	429.59-429.62	429.40-407.70	-0.0014
Shallow Alluvium to Deep Alluvium	PZ-113-AS / PZ-113-AD	429.48-429.62	425.92-356.36	-0.002
Shallow Alluvium to Deep Alluvium	PZ-300-AS / PZ-300-AD	434.02-430.63	433.70-408.60	0.14
Shallow Alluvium to St. Louis/Salem	PZ-114-AS / PZ-115-SS	429.93-414.31	424.78-370.03	0.28
Shallow Alluvium to St. Louis/Salem	PZ-205-AS / PZ-205-SS	429.85-419.11	416.88-367.56	0.22
Deep Alluvium to St. Louis/Salem	PZ-113-AD / PZ-113-SS	429.62-429.65	356.36-306.36	-0.0006
Deep Alluvium to St. Louis/Salem	PZ-300-AD / PZ-300-SS	430.63-426.58	408.60-359.61	0.08
St. Louis/Salem to Deep Salem	PZ-100-SS / PZ-100-SD	412.87-372.88	400.57-244.65	0.26
St. Louis/Salem to Deep Salem	PZ-104-SS / PZ-104-SD	362.99-360.25	342.16-241.25	0.03
St. Louis/Salem to Deep Salem	PZ-106-SS / PZ-106-SD	357.55-350.17	300.75-265.75	0.21
Deep Salem to Keokuk	PZ-100-SD / PZ-100-KS	372.88-435.71	244.65-104.86	-0.45
Deep Salem to Keokuk	PZ-104-SD / PZ-104-KS	360.25-442.94	241.25-80.05	-0.51
Deep Salem to Keokuk	PZ-106-SD / PZ-106-KS	350.17-440.50	265.75-93.07	-0.52
Deep Salem to Keokuk	PZ-111-SD / PZ-111-KS	428.90-440.13	254.92-97.18	-0.07

Δ H = Head differential
Δ L = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the contect of this table to represent an upward gradient (i_v).
Thus, a positive value represent a downward gradient.

Table 3-15. Vertical Hydraulic Gradient - May 3, 1996
West Lake Landfill

Interval Monitored	Piezometer Pair	Δ H	Δ L	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS / PZ-302-AI	431.26-431.10	432.40-412.50	0.008
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS / PZ-304-AI	431.07-431.13	429.40-407.70	-0.003
Shallow Alluvium to Deep Alluvium	PZ-113-AS / PZ-113-AD	430.79-430.81	425.92-356.36	-0.003
Shallow Alluvium to St. Louis/Salem	PZ-114-AS / PZ-115-SS	431.60-423.51	424.78-370.03	0.15
Shallow Alluvium to St. Louis/Salem	PZ-205-AS / PZ-205-SS	430.68-420.13	416.88-367.56	0.21
Deep Alluvium to St. Louis/Salem	PZ-113-AD / PZ-113-SS	430.81-430.89	356.36-306.36	-0.002
St. Louis/Salem to Deep Salem	PZ-100-SS / PZ-100-SD	412.83-367.82	400.57-244.65	0.29
St. Louis/Salem to Deep Salem	PZ-104-SS / PZ-104-SD	376.44-370.88	342.16-241.25	0.06
St. Louis/Salem to Deep Salem	PZ-106-SS / PZ-106-SD	371.56-364.81	300.75-265.75	0.19
Deep Salem to Keokuk	PZ-100-SD / PZ-100-KS	367.82-435.56	244.65-104.86	-0.48
Deep Salem to Keokuk	PZ-104-SD / PZ-104-KS	370.88-443.35	241.25-80.05	-0.45
Deep Salem to Keokuk	PZ-106-SD / PZ-106-KS	364.81-440.68	365.75-93.07	-0.43
Deep Salem to Keokuk	PZ-111-SD / PZ-111-KS	429.00-440.16	254.92-97.18	-0.07

Δ H = Head differential
Δ L = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the contect of this table to represent an upward gradient (i_v).
Thus, a positive value represent a downward gradient.

Table 3-16. Vertical Hydraulic Gradient - July 12, 1996
West Lake Landfill

Interval Monitored	Piezometer Pair	Δ H	Δ L	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS / PZ-302-AI	434.12-434.05	432.40-412.50	0.0035
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS / PZ-304-AI	434.14-434.20	429.40-407.70	-0.003
Shallow Alluvium to Deep Alluvium	PZ-113-AS / PZ-113-AD	434.39-434.35	425.92-356.36	0.0006
Shallow Alluvium to St. Louis/Salem	PZ-114-AS / PZ-115-SS	434.46-421.85	424.78-370.03	0.23
Shallow Alluvium to St. Louis/Salem	PZ-205-AS / PZ-205-SS	433.71-422.97	416.88-367.56	0.22
Deep Alluvium to St. Louis/Salem	PZ-113-AD / PZ-113-SS	434.35-434.46	356.36-306.36	-0.002
St. Louis/Salem to Deep Salem	PZ-100-SS / PZ-100-SD	412.94-367.04	400.57-244.65	0.29
St. Louis/Salem to Deep Salem	PZ-104-SS / PZ-104-SD	371.10-367.77	342.16-241.25	0.03
St. Louis/Salem to Deep Salem	PZ-106-SS / PZ-106-SD	368.46-367.31	300.75-265.75	0.03
Deep Salem to Keokuk	PZ-100-SD / PZ-100-KS	367.04-439.35	244.65-104.86	-0.52
Deep Salem to Keokuk	PZ-104-SD / PZ-104-KS	367.77-447.40	241.25-80.05	-0.49
Deep Salem to Keokuk	PZ-106-SD / PZ-106-KS	367.31-444.46	265.75-93.07	-0.45
Deep Salem to Keokuk	PZ-111-SD / PZ-111-KS	433.46-443.66	254.92-97.18	-0.06

Δ H = Head differential
Δ L = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the contect of this table to represent an upward gradient (i_v). Thus, a positive value represent a downward gradient.

Table 3-17. Horizontal Groundwater Velocities, West Lake Landfill

Formation	Gradient	Effective Porosity		
		0.10	0.20	0.30
Hydraulic Conductivity		Velocity (ft/yr)		
Unconsolidated Material $K = 1.0 \times 10^{-4}$ cm/sec	0.0014	NA	NA	0.5
St. Louis/Upper Salem $K = 1.1 \times 10^{-6}$ cm/sec	0.049	0.6	0.3	NA
	0.48	5.0	3.0	NA
Keokuk $K = 4.5 \times 10^{-6}$ cm/sec	0.0015	0.07	0.03	NA
	0.0036	0.2	0.1	NA

Note:

The hydraulic conductivity (K) values reported above are the mean of saturated zone slug test and saturated zone packer test results in the respective bedrock formations, and the mean of the shallow and deep alluvial piezometer slug tests in the unconsolidated materials.

NA = Not applicable. Horizontal groundwater velocities were not calculated for these effective porosities.

Table 4-1. Liquid Analyte List

Metals	
Antimony, Total and Dissolved	Lead, Total and Dissolved
Arsenic, Total and Dissolved	Magnesium, Total and Dissolved
Barium, Total and Dissolved	Manganese, Total and Dissolved
Beryllium, Total and Dissolved	Mercury, Total and Dissolved
Boron, Total and Dissolved	Nickel, Total and Dissolved
Cadmium, Total and Dissolved	Selenium, Total and Dissolved
Calcium, Total and Dissolved	Silver, Total and Dissolved
Chromium, Total and Dissolved	Sodium, Total and Dissolved
Cobalt, Total and Dissolved	Thallium, Total and Dissolved
Copper, Total and Dissolved	Vanadium, Total and Dissolved
Iron, Total and Dissolved	Zinc, Total and Dissolved
General Parameters	
Ammonia as N	Phosphorus, Total
Chemical Oxygen Demand (COD)	Sulfate as SO4
Chloride	Sulfide
Cyanide, Total	Total Petroleum Hydrocarbons
Fluoride	Total Dissolved Solids (TDS)
Hardness, Total (calculated)	Total Organic Carbon (TOC)
Nitrate/Nitrite	
Radionuclides	
Gross Alpha, Total and Dissolved	Thorium-230, Total and Dissolved
Gross Beta, Total and Dissolved	Uranium-234, 235, 238, Total and Dissolved
Radium-226, Total and Dissolved	
Volatile Organic Compounds (VOCs)	
Acetone	1,2-Dichloropropane
Acrylonitrile	1,3-cis-Dichloropropene
Benzene	1,3-trans-Dichloropropene
Bromochloromethane	Ethylbenzene
Bromodichloromethane	2-Hexanone
Bromoform (Tribromomethane)	Methyl ethyl ketone (2-Butanone)
Bromomethane (Methyl bromide)	Methyl iodide (iodomethane)
Carbon disulfide	Methyl isobutyl ketone (4-Methyl-2-Pentanone)
Carbon tetrachloride	Methylene Bromide (Dibromomethane)
Chlorobenzene	Methylene Chloride (Dichloromethane)
Chloroethane	Styrene
Chloroform (Trichloromethane)	1,1,1,2-Tetrachloromethane
Chloromethane (Methyl chloride)	1,1,2,2-Tetrachloroethane
1,2-Dibromo-3-chloropropane	Tetrachloroethene
Dibromochloromethane (Chlorodibromomethane)	Toluene
1,2-Dibromomethane (Ethylene dibromide)	1,1,1-Trichloroethane
Trans-1,4-Dichloro-2-butene	1,1,2-Trichloroethane
1,2-Dichlorobenzene (o-DCB)	Trichloroethene
1,3-Dichlorobenzene (m-DCB)	Trichlorofluoromethane
1,4-Dichlorobenzene (p-DCB)	1,2,4-Trichlorobenzene
1,1-Dichloroethane	1,2,3-Trichloropropane
1,2-Dichloroethane	Vinyl Acetate
1,1-Dichloroethene	Vinyl Chloride
1,2-cis-Dichloroethene	Xylenes
1,2-trans-Dichloroethene	

Table 4-1. Liquid Analyte List (continued)

Semivolatile Organic Compounds (SVOCs)	
Acenaphthene	Di-n-butyl phthalate
Acenaphthylene	2,4-Dinitrophenol
Anthracene	2,4-Dinitrotoluene
Benzo(a)anthracene	2,6-Dinitrotoluene
Benzo(a)pyrene	4,6-Dinitro-o-cresol
Benzo(b)fluoranthene	Bis-2-Ethylhexyl)phthalate
Benzo(ghi)perylene	Fluoranthene
Benzo(k)fluoranthene	Fluorene
4-Bromophenyl phenyl ether	Hexachlorobenzene
Butyl benzyl phthalate	Hexachlorobutadiene
Carbazole	Hexachlorocyclopentadiene
p-Chloro-m-cresol (4-Chloro-3-methylphenol)	Hexachloroethane
4-Chloroaniline	Indeno(1,2,3-cd)pyrene
Bis(2-Chloroethoxy)methane	Isophorone
Bis(2-Chloroethyl)ether	2-Methylnapthalene
Bis(2-Chloroisopropyl)ether	Naphthalene
2-Chloronaphthalene	2-Nitroaniline
2-Chlorophenol	3-Nitroaniline
4-Chlorophenyl phenyl ether	4-Nitroaniline
Chrysene	Nitrobenzene
m-Cresol (3-Methylphenol)	2-Nitrophenol
o-Cresol (2-Methylphenol)	4-Nitrophenol
p-Cresol (4-Methylphenol)	N-Nitrosodi-n-propylamine
Dibenzo(a,h)anthracene	N-Nitrosodiphenylamine
Dibenzofuran	Pentachlorophenol
3,3-Dichlorobenzidene	Phenanthrene
2,4-Dichlorophenol	Phenol
Diethyl phthalate	Pyrene
Dimethyl phthalate	2,4,5-Trichlorophenol
2,4-Dimethylphenol	2,4,6-Trichlorophenol
Pesticides and Polychlorinated Biphenyls (PCBs)	
Aldrin	Endrin
Alpha-BHC	Endrin aldehyde
Beta-BHC	Endrin ketone
Delta-BHC	Heptachlor
Gamma-BHC (Lindane)	Heptachlor epoxide
Alpha-Chlordane	Methoxychlor
Gamma-Chlordane	Toxaphene
4,4'-DDD	Aroclor-1016
4,4'-DDE	Aroclor-1221
4,4'-DDT	Aroclor-1232
Dieldrin	Arocolor-1242
Endosulfan I	Aroclor-1248
Endosulfan II	Aroclor-1254
Endosulfan sulfate	Aroclor-1260

Table 4-2. Background bedrock groundwater quality results (metals and conventional parameters) December 1995 sampling event

Parameter	GW-300-SS (mg/l)
Calcium	73.9
Potassium	<5
Magnesium	56.4
Sodium	10.7
Chloride	6
Sulfate	20
Bicarbonate as alkalinity	500
Nitrate/Nitrite	<0.1
Chemical Oxygen Demand	50

Table 4-3. Background bedrock groundwater radionuclide results (pCi/l) December 1995 sampling event

Parameter	GW-300-SS (unfiltered)	GW-300-SS (filtered)
Gross alpha	3.51 ± 2.69	<3.32
Gross beta	4.37 ± 2.25	<3.72
Radium-226	0.78 ± 0.09	0.60 ± 0.08
Radium-228	0.39 ± 0.37	<0.43
Uranium-238	0.25 ± 0.13	0.50 ± 0.20
Uranium-235/236	0.32 ± 0.17	0.13 ± 0.11
Uranium-234	0.80 ± 0.26	0.89 ± 0.28
Thorium-232	<0.092	<0.11
Thorium-230	0.84 ± 0.29	0.29 ± 0.17
Thorium-228	<0.13	<0.15

Table 4-4. Background bedrock groundwater quality summary PZ-300-SS, PZ-301-SS, PZ-204A-SS

Parameter	Range of background concentrations (mg/l)
Antimony (Dissolved)	<0.003 to 0.008
Antimony (Total)	<0.002 to 0.009
Arsenic (Dissolved)	<0.002 to 0.008
Arsenic (Total)	<0.002 to 0.007
Barium (Dissolved)	0.022 to 0.079
Barium (Total)	0.037 to 0.1
Beryllium (Dissolved)	<0.001 to <0.001
Beryllium (Total)	<0.001 to <0.001
Boron (Dissolved)	<0.1 to 0.636
Boron (Total)	<0.1 to 0.8
Cadmium (Dissolved)	<0.005 to <0.005
Cadmium (Total)	<0.005 to <0.005
Calcium (Dissolved)	40.1 to 66.9
Calcium (Total)	41.0 to 75.4
Chromium (Dissolved)	<0.01 to <0.01
Chromium (Total)	<0.01 to <0.01
Cobalt (Dissolved)	<0.02 to <0.02
Cobalt (Total)	<0.02 to <0.02
Copper (Dissolved)	<0.02 to <0.02
Copper (Total)	<0.02 to <0.02
Iron (Dissolved)	<0.04 to 0.665
Iron (Total)	<0.04 to 1.02
Lead (Dissolved)	<0.002 to <0.002
Lead (Total)	<0.002 to 0.003
Magnesium (Dissolved)	25.1 to 37.6
Magnesium (Total)	25.4 to 56.4
Manganese (Dissolved)	0.045 to 0.063
Manganese (Total)	0.045 to 0.064
Mercury (Dissolved)	<0.0002 to <0.0002
Mercury (Total)	<0.0002 to <0.0002
Nickel (Dissolved)	<0.040 to <0.040
Nickel (Total)	<0.040 to <0.040
Selenium (Dissolved)	<0.002 to <0.002
Selenium (Total)	<0.002 to <0.002
Silver (Dissolved)	<0.010 to <0.010
Silver (Total)	<0.010 to <0.010
Sodium (Dissolved)	30.1 to 153
Sodium (Total)	28.1 to 154
Thallium (Dissolved)	<0.002 to <0.002
Thallium (Total)	<0.002 to <0.002
Vanadium (Dissolved)	<0.010 to <0.010
Vanadium (Total)	<0.010 to <0.010
Zinc (Dissolved)	<0.030 to <0.030
Zinc (Total)	<0.030 to 0.133

Table 4-4. Background bedrock groundwater quality summary PZ-300-SS, PZ-301-SS, PZ-204A-SS (continued)

Parameter	Range of background concentrations (mg/l)
Conventionals	
Ammonia as N	<0.1 to 0.2
Chemical Oxygen Demand	<15 to 50
Chloride	4 to 7
Cyanide, Total	<0.010 to <0.010
Fluoride	0.43 to 1.8
Hardness, Total	220 to 360
Nitrate/Nitrite	<0.1 to 0.2
Phosphorus, Total	0.04 to 1.5
Sulfate, as SO_4	20 to 73
Sulfide as S	<1 to 1
Total Dissolved Solids	432 to 640
Total Organic Carbon	<1 to 7
Radionuclides (pCi/l)	<3.32 to 17.9 ± 5.24
Gross Alpha (Dissolved)	3.51 ± 2.69 to 28.8 ± 7.21
Gross Alpha (Total)	<3.72 to 9.28 ± 3.86
Gross Beta (Dissolved)	4.37 ± 2.25 to 20.5 ± 4.37
Gross Beta (Total)	<0.43 to 1.42 ± 0.563
Radium-226 (Dissolved)	0.78 ± 0.09 to 3.33 ± 0.769
Radium-226 (Total)	0.89 ± 0.28 to 8.2 ± 1.37
Uranium-234 (Dissolved)	0.80 ± 0.26 to 9.78 ± 1.81
Uranium-234 (Total)	0.141 to 0.769 ± 0.449
Uranium-235/236 (Dissolved)	0.169 to 0.516 ± 0.35
Uranium-235/236 (Total)	0.50 ± 0.20 to 3.36 ± 0.888
Uranium-238 (Dissolved)	0.25 ± 0.13 to 4.55 ± 1.25
Uranium-238 (Total)	<0.502 to 0.29 ± 0.17
Thorium-230 (Dissolved)	<0.736 to 0.84 ± 0.29
Thorium-230 (Total)	

Table 4-5. Drilling Water analytical results

Parameter Group	Parameter	Result (mg/l)
VOC	Chloroform	0.005
Metals	Barium	0.023
	Calcium	24.4
	Iron	2.72
	Magnesium	11.8
	Manganese	0.037
	Sodium	20.8
Conventionals	Hardness	98
	Total Dissolved Solids	250
	Chloride	19
	Fluoride	1
	Nitrate-Nitrite	1.4
	Phosphorus	0.1
	TOC	3
	Sulfide	3
	Ammonia	1
	Sulfate	85
	COD	28

Table 4-6. Background alluvial groundwater quality results (metals and conventional parameters) December 1995 sampling event

Parameter	GW-300-AS (mg/l)	GW-300-AD (mg/l)	GW-S-80 (mg/l)	GW-I-50 (mg/l)	GW-MW-107 (mg/l)
Calcium	142	176	151	159	131
Potassium	<5	6.1	5.4	<5	<5
Magnesium	41.6	61.1	51.5	57.9	52.6
Sodium	73	38.6	66.1	35.4	35.8
Chloride	210	150	250	160	130
Sulfate	110	100	67	26	70
Bicarbonate as alkalinity	280	460	330	460	400
Nitrate/Nitrite	<0.1	<0.1	<0.1	<0.1	<0.1
Chemical Oxygen Demand	<20	<20	<20	<20	40

**Table 4-7. Background alluvial groundwater radionuclide results (pCi/l)
December 1995 sampling event**

	GW-300-AS (unfiltered)	GW-300-AS (filtered)	GW-300-AD (unfiltered)	GW-300-AD (filtered)
Gross Alpha	<3.53	<4.18	5.49 ± 3.51	<4.05
Gross Beta	9.34 ± 1.64	4.08 ± 2.28	8.47 ± 2.43	<4.07
Ra-226	0.31 ± 0.05	0.20 ± 0.003	0.51 ± 0.07	0.35 ± 0.05
Ra-228	<0.55	<0.32	1.00 ± 0.54	<0.41
U-238	0.57 ± 0.20	0.55 ± 0.18	0.26 ± 0.13	0.17 ± 0.09
U-235/236	<0.17	<0.13	<0.13	<0.10
U-234	0.74 ± 0.23	0.58 ± 0.19	0.32 ± 0.15	0.40 ± 0.15
Th-232	0.22 ± 0.14	<0.21	0.13 ± 0.11	0.12 ± 0.08
Th-230	0.51 ± 0.21	0.26 ± 0.18	0.83 ± 0.30	0.50 ± 0.19
Th-228	<0.14	<0.20	0.18 ± 0.13	<0.10

	GW-S-80 (unfiltered)	GW-S-80 (filtered)	GW-1-50 (unfiltered)	GW-1-50 (filtered)
Gross Alpha	56.1 ± 9.5	<7.02	<4.32	<4.06
Gross Beta	53.1 ± 6.2	<3.94	5.12 ± 2.52	6.02 ± 3.00
Ra-226	0.44 ± 0.06	0.19 ± 0.04	0.42 ± 0.06	0.29 ± 0.04
Ra-228	<0.65	<0.42	<0.40	<0.48
U-238	1.19 ± 0.35	0.63 ± 0.21	0.15 ± 010	<0.097
U-235/236	0.27 ± 0.17	0.16 ± 0.11	0.18 ± 0.12	<0.14
U-234	0.99 ± 0.31	0.88 ± 0.26	0.43 ± 0.18	0.25 ± 0.13
Th-232	0.86 ± 0.28	<0.11	0.17 ± 0.12	0.21 ± 0.13
Th-230	1.48 ± 0.40	0.31 ± 0.16	1.00 ± 0.33	0.93 ± 0.30
Th-228	0.85 ± 0.28	<0.13	<0.12	<0.11

Table 4-7. Background alluvial groundwater radionuclide results (pCi/l) December 1995 sampling event (continued)

	GW-MW-107 (unfiltered)	GW-MW-107 (filtered)
Gross Alpha	<4.64	<3.03
Gross Beta	4.38 ± 2.49	<3.96
Ra-226	<0.066	0.069 ± 0.029
Ra-228	<0.068	<0.039
U-238	0.26 ± 0.13	0.36 ± 0.16
U-235/236	<0.09	<0.10
U-234	0.43 ± 0.17	0.39 ± 0.17
Th-232	0.33 ± 0.17	<0.085
Th-230	0.29 ± 0.16	0.27 ± 0.15
Th-228	0.26 ± 0.15	<0.11

Table 4-8. Background alluvial groundwater quality summary
Monitoring wells MW-107, S-80, and I-50 and piezometers PZ-300-AS and PZ-300-AD

Parameter	Range of background concentrations (mg/l)
Antimony (Dissolved)	<0.003 to <0.003
Antimony (Total)	<0.003 to <0.003
Arsenic (Dissolved)	0.004 to 0.004
Arsenic (Total)	0.004 to 0.004
Barium (Dissolved)	0.152 to 0.178
Barium (Total)	0.152 to 0.182
Beryllium (Dissolved)	<0.001 to <0.001
Beryllium (Total)	<0.001 to <0.001
Boron (Dissolved)	<0.1 to <0.1
Boron (Total)	<0.1 to <0.1
Cadmium (Dissolved)	<0.005 to <0.005
Cadmium (Total)	<0.005 to <0.005
Calcium (Dissolved)	158 to 159
Calcium (Total)	131 to 176
Chromium (Dissolved)	<0.010 to <0.010
Chromium (Total)	<0.010 to 0.011
Cobalt (Dissolved)	<0.020 to <0.020
Cobalt (Total)	<0.020 to <0.020
Copper (Dissolved)	<0.020 to <0.020
Copper (Total)	<0.020 to <0.020
Iron (Dissolved)	3.33 to 4.06
Iron (Total)	1.98 to 2.83
Lead (Dissolved)	<0.002 to <0.002
Lead (Total)	<0.002 to <0.002
Magnesium (Dissolved)	56.4 to 58.0
Magnesium (Total)	41.6 to 57.8
Manganese (Dissolved)	3.09 to 3.32
Manganese (Total)	3.05 to 3.14
Mercury (Dissolved)	<0.0002 to <0.0002
Mercury (Total)	<0.0002 to <0.0002
Nickel (Dissolved)	<0.04 to <0.04
Nickel (Total)	<0.04 to <0.04
Selenium (Dissolved)	<0.002 to <0.002
Selenium (Total)	<0.002 to <0.002
Silver (Dissolved)	<0.010 to <0.010
Silver (Total)	<0.010 to <0.010
Sodium (Dissolved)	43.4 to 44.9
Sodium (Total)	35.4 to 73.0
Thallium (Dissolved)	<0.002 to <0.002
Thallium (Total)	<0.002 to <0.002
Vanadium (Dissolved)	<0.010 to <0.010
Vanadium (Total)	<0.010 to <0.010
Zinc (Dissolved)	<0.030 to <0.030
Zinc (Total)	<0.030 to <0.030

Table 4-8. Background alluvial groundwater quality summary
Monitoring wells MW-107, S-80, and I-50 and piezometers PZ-300-AS and PZ-300-AD
(continued)

Parameter	Range of background concentrations (mg/l)
Conventionals	
Ammonia as N	0.4 to 0.4
Chemical Oxygen Demand	<15 to 40
Chloride	130 to 215
Cyanide, Total	<0.010 to <0.010
Fluoride	0.27 to 0.36
Hardness, Total	660 to 700
Nitrate/Nitrite	<0.1 to <0.1
Phosphorus, Total	0.39 to 0.63
Sulfate, as SO_4	62 to 110
Sulfide as S	<1 to <1
Total Dissolved Solids	933 to 940
Total Organic Carbon	2 to 3
Radionuclides (pCi/l)	
Gross Alpha (Dissolved)	<3.03 to <8.19
Gross Alpha (Total)	<3.53 to 56.1 ± 9.5
Gross Beta (Dissolved)	<3.94 to 6.02 ± 3.00
Gross Beta (Total)	4.38 ± 2.49 to 53.1 ± 6.2
Radium-226 (Dissolved)	0.069 ± 0.029 to 0.35 ± 0.05
Radium-226 (Total)	<0.066 to 0.51 ± 0.07
Uranium-234 (Dissolved)	0.25 ± 0.13 to 0.88 ± 0.26
Uranium-234 (Total)	0.32 ± 0.15 to 0.99 ± 0.31
Uranium-235/236 (Dissolved)	<0.010 to 0.16 ± 0.11
Uranium-235/236 (Total)	<0.09 to 0.27 ± 0.17
Uranium-238 (Dissolved)	<0.097 to 0.63 ± 0.21
Uranium-238 (Total)	<0.258 to 1.19 ± 0.35
Thorium-230 (Dissolved)	<0.627 to 0.93 ± 0.30
Thorium-230 (Total)	<0.415 to 1.48 ± 0.40

Table 4-9. Comparison of St. Louis/Upper Salem detection results to background bedrock groundwater quality

Parameter	Range of background concentrations (mg/l)	Range of detection results (mg/l)	Piezometer exhibiting maximum detection concentration
Antimony (Dissolved)	<0.003 to 0.008	<0.003 to 0.004	PZ-1201-SS
Antimony (Total)	<0.002 to 0.009	<0.003 to 0.007	PZ-102R-SS
Arsenic (Dissolved)	<0.002 to 0.008	<0.002 to 0.007	PZ-113-SS
Arsenic (Total)	0.002 to 0.007	<0.002 to 0.006	PZ-113-SS
Barium (Dissolved)	0.022 to 0.079	0.033 to 0.251	PZ-110-SS
Barium (Total)	0.037 to 0.1	0.054 to 0.252	PZ-110-SS
Beryllium (Dissolved)	<0.001 to <0.001	<0.001 to <0.001	
Beryllium (Total)	<0.001 to <0.001	<0.001 to <0.001	
Boron (Dissolved)	<0.1 to 0.636	<0.1 to 0.282	PZ-110-SS
Boron (Total)	<0.1 to 0.80	<0.1 to 0.30	PZ-110-SS
Cadmium (Dissolved)	<0.005 to <0.005	<0.005 to <0.005	
Cadmium (Total)	<0.005 to <0.005	<0.005 to <0.005	
Calcium (Dissolved)	40.1 to 66.9	49.6 to 219	PZ-110-SS
Calcium (Total)	41.0 to 75.4	60 to 214	PZ-110-SS
Chromium (Dissolved)	<0.01 to <0.01	<0.01 to 0.016	PZ-113-SS
Chromium (Total)	<0.01 to <0.01	<0.01 to <0.01	
Cobalt (Dissolved)	<0.02 to <0.02	<0.02 to <0.02	
Cobalt (Total)	<0.02 to <0.02	<0.02 to <0.02	
Copper (Dissolved)	<0.02 to <0.02	<0.02 to <0.02	
Copper (Total)	<0.02 to <0.02	<0.02 to 0.045	
Iron (Dissolved)	<0.04 to 0.665	<0.04 to 4.24	PZ-110-SS
Iron (Total)	<0.04 to 1.02	<0.04 to 5.87	PZ-110-SS
Lead (Dissolved)	<0.002 to <0.002	<0.002 to <0.002	
Lead (Total)	<0.002 to 0.003	<0.002 to 0.008	
Magnesium (Dissolved)	25.1 to 37.6	26.3 to 80.0	PZ-110-SS
Magnesium (Total)	25.4 to 56.4	29.1 to 81	PZ-110-SS
Manganese (Dissolved)	0.045 to 0.063	<0.01 to 0.375	PZ-201A-SS
Manganese (Total)	0.045 to 0.064	0.017 to 0.528	PZ-201A-SS
Mercury (Dissolved)	<0.0002 to <0.0002	<0.0002 to <0.0002	
Mercury (Total)	<0.0002 to <0.0002	<0.0002 to <0.0002	
Nickel (Dissolved)	<0.040 to <0.040	<0.04 to 0.048	PZ-110-SS
Nickel (Total)	<0.040 to <0.040	<0.04 to 0.055	PZ-110-SS
Selenium (Dissolved)	<0.002 to <0.002	<0.002 to 0.003	PZ-102R-SS
Selenium (Total)	<0.002 to <0.002	<0.002 to 0.003	PZ-102R-SS
Silver (Dissolved)	<0.010 to <0.010	<0.010 to <0.010	
Silver (Total)	<0.010 to <0.010	<0.010 to <0.010	
Sodium (Dissolved)	30.1 to 153	11 to 114	PZ-110-SS
Sodium (Total)	28.1 to 154	11 to 115	PZ-110-SS
Thallium (Dissolved)	<0.002 to <0.002	<0.002 to <0.002	
Thallium (Total)	<0.002 to <0.002	<0.002 to <0.002	
Vanadium (Dissolved)	<0.010 to <0.010	<0.010 to <0.010	
Vanadium (Total)	<0.010 to <0.010	<0.010 to <0.010	
Zinc (Dissolved)	<0.030 to <0.030	<0.030 to 0.044	PZ-110-SS
Zinc (Dissolved)	<0.030 to <0.030	<0.030 to 0.044	PZ-110-SS
Zinc (Total)	<0.030 to 0.133	<0.030 to 0.227	PZ-110-SS

Table 4-9. **Comparison of St. Louis/Upper Salem detection results to background bedrock groundwater quality (continued)**

Parameter	Range of background (mg/l)	Range of detection (mg/l)	Piezometer exhibiting
Conventionals			
Ammonia as N	<0.1 to 0.2	<0.1 to 0.8	PZ-100-SS
Chemical Oxygen Demand	<15 to 50	<15 to 81	PZ-110-SS
Chloride	4 to 7	<3 to 215	PZ-110-SS
Cyanide, Total	<0.010 to <0.010	<0.010 to <0.010	
Fluoride	0.43 to 1.8	0.49 to 2.7	PZ-113-SS
Hardness, Total	220 to 360	290 to 900	PZ-110-SS
Nitrate/Nitrite	<0.1 to 0.2	<0.1 to 0.2	PZ-1201-SS
Phosphorus, Total	0.04 to 1.5	0.06 to 1.6	PZ-1201-SS
Sulfate, as SO_4	20 to 73	26 to 141	PZ-102R-SS
Sulfide as S	<1 to 1	<1 to 4.3	PZ-102R-SS
Total Dissolved Solids	432 to 640	364 to 1418	PZ-110-SS
Total Organic Carbon	<1 to 7	<1 to 23	PZ-110-SS
Radionuclides (pCi/l)			
Gross Alpha (Dissolved)	<3.32 to 17.19 ± 5.24	<2.97 to 17.4 ± 5	PZ-100-SS
Gross Alpha (Total)	3.51 ± 2.69 to 28.8 ± 7.21	<4.61 to 29.3 ± 11.9	PZ-1201-SS
Gross Beta (Dissolved)	<3.72 to 9.28 ± 3.86	<3.6 to 19 ± 2.28	PZ-1201-SS
Gross Beta (Total)	4.37 ± 2.25 to 20.5 ± 4.37	<4.49 to 35.2 ± 10.7	PZ-1201-SS
Radium-226 (Dissolved)	<0.43 to 1.42 ± 0.563	<0.412 to 2.53 ± 0.733	PZ-106-SS
Radium-226 (Total)	0.78 ± 0.09 to 3.33 ± 0.769	<0.426 to 6.33 ± 1.26	PZ-106-SS
Uranium-234 (Dissolved)	0.89 ± 0.28 to 8.2 ± 1.37	<0.343 to 12.7 ± 1.46	PZ-100-SS
Uranium-234 (Total)	0.80 ± 0.26 to 9.78 ± 1.81	0.202 ± 0.146 to 20 ± 1.39	PZ-104-SS
Uranium-235/236 (Dissolved)	<0.141 to 0.769 ± 0.449	<0.151 to 1.25 ± 0.851	PZ-201A-SS
Uranium-235/236 (Total)	<0.169 to 0.516 ± 0.35	<0.123 to 0.746 ± 0.418	PZ-100-SS
Uranium-238 (Dissolved)	0.50 ± 0.20 to 3.36 ± 0.888	<0.151 to 6.27 ± 1.2	PZ-100-SS
Uranium-238 (Total)	0.25 ± 0.13 to 4.55 ± 1.25	0.134 to 6.39 ± 1.15	PZ-100-SS
Thorium-230 (Dissolved)	<0.502 to 0.29 ± 0.17	<0.442 to 0.934 ± 0.392	PZ-206-SS
Thorium-230 (Total)	<0.736 to 0.84 ± 0.29	<0.535 to 2.41 ± 1.1	PZ-1201-SS

Table 4-10. Comparison of Deep Salem detection results to background bedrock groundwater quality

Parameter	Range of background concentrations (mg/l)	Range of detection results (mg/l)	Piezometer exhibiting maximum detection concentration
Antimony (Dissolved)	<0.003 to 0.008	<0.003 to <0.003	
Antimony (Total)	<0.002 to 0.009	<0.003 to <0.003	
Arsenic (Dissolved)	<0.002 to 0.008	<0.002 to 0.002	PZ-100-SD
Arsenic (Total)	0.002 to 0.007	<0.002 to 0.002	PZ-100SD; PZ-106-SD
Barium (Dissolved)	0.022 to 0.079	0.045 to 0.273	PZ-100-SD
Barium (Total)	0.037 to 0.1	0.05 to 0.291	PZ-100-SD
Beryllium (Dissolved)	<0.001 to <0.001	<0.001 to <0.001	
Beryllium (Total)	<0.001 to <0.001	<0.001 to <0.001	
Boron (Dissolved)	<0.1 to 0.636	<0.1 to <0.1	
Boron (Total)	<0.1 to 0.80	<0.1 to <0.1	
Cadmium (Dissolved)	<0.005 to <0.005	<0.005 to <0.005	
Cadmium (Total)	<0.005 to <0.005	<0.005 to <0.005	
Calcium (Dissolved)	40.1 to 66.9	75.8 to 119	PZ-104-SD
Calcium (Total)	41.0 to 75.4	81.2 to 116	PZ-104-SD
Chromium (Dissolved)	<0.01 to <0.01	<0.01 to <0.01	PZ-113-SS
Chromium (Total)	<0.01 to <0.01	<0.01 to <0.01	
Cobalt (Dissolved)	<0.02 to <0.02	<0.02 to <0.02	
Cobalt (Total)	<0.02 to <0.02	<0.02 to <0.02	
Copper (Dissolved)	<0.02 to <0.02	<0.02 to <0.02	
Copper (Total)	<0.02 to <0.02	<0.02 to <0.02	
Iron (Dissolved)	<0.04 to 0.665	<0.04 to 0.945	MW-1204
Iron (Total)	<0.04 to 1.02	0.119 to 2.09	PZ-100-SD
Lead (Dissolved)	<0.002 to <0.002	<0.002 to <0.002	
Lead (Total)	<0.002 to 0.003	<0.002 to <0.002	
Magnesium (Dissolved)	25.1 to 37.6	34.0 to 53.9	PZ-111-SD
Magnesium (Total)	25.4 to 56.4	34.3 to 53.4	PZ-111-SD
Manganese (Dissolved)	0.045 to 0.063	0.016 to 0.238	PZ-106-SD
Manganese (Total)	0.045 to 0.064	0.017 to 0.332	PZ-100-SD
Mercury (Dissolved)	<0.0002 to <0.0002	<0.0002 to <0.0002	
Mercury (Total)	<0.0002 to <0.0002	<0.0002 to <0.0002	
Nickel (Dissolved)	<0.040 to <0.040	<0.04 to <0.04	
Nickel (Total)	<0.040 to <0.040	<0.04 to <0.04	
Selenium (Dissolved)	<0.002 to <0.002	<0.002 to <0.002	
Selenium (Total)	<0.002 to <0.002	<0.002 to <0.002	
Silver (Dissolved)	<0.010 to <0.010	<0.010 to <0.010	
Silver (Total)	<0.010 to <0.010	<0.010 to <0.010	
Sodium (Dissolved)	30.1 to 153	11 to 59.9	PZ-106-SD
Sodium (Total)	28.1 to 154	11 to 59.1	PZ-106-SD
Thallium (Dissolved)	<0.002 to <0.002	<0.002 to <0.002	
Thallium (Total)	<0.002 to <0.002	<0.002 to <0.002	
Vanadium (Dissolved)	<0.010 to <0.010	<0.010 to <0.010	
Vanadium (Total)	<0.010 to <0.010	<0.010 to <0.010	
Zinc (Dissolved)	<0.030 to <0.030	<0.030 to 0.053	PZ-111-SD
Zinc (Total)	<0.030 to 0.133	<0.030 to 0.103	PZ-111-SD

Table 4-10. Comparison of Deep Salem detection results to background bedrock groundwater quality (continued)

Parameter	Range of background concentrations (mg/l)	Range of detection results (mg/l)	Piezometer exhibiting maximum detection concentration
Conventionals (mg/l)			
Ammonia as N	<0.1 to 0.2	<0.1 to 0.5	PZ-100-SD, PZ-106-SD
Chemical Oxygen Demand	<15 to 50	<15 to 92	PZ-106-SD
Chloride	4 to 7	<3 to 56	PZ-104-SD
Cyanide, Total	<0.010 to <0.010	<0.01 to <0.01	
Fluoride	0.43 to 1.8	0.77 to 2.4	PZ-1204-SD
Hardness, Total	220 to 360	340 to 500	PZ-104-SD
Nitrate/Nitrite	<0.1 to 0.2	<0.1 to 0.3	PZ-106-SD
Phosphorus, Total	0.04 to 1.5	<0.01 to 0.37	PZ-111-SD
Sulfate, as SO_4	20 to 73	10 to 120	PZ-106-SD
Sulfide as S	<1 to 1	<1 to 1	PZ-106-SD; PZ-111-SD; MW-1204
Total Dissolved Solids	432 to 640	340 to 665	PZ-106-SD
Total Organic Carbon	<1 to 7	<1 to 26	PZ-106-SD
Radionuclides (pCi/l)			
Gross Alpha (Dissolved)	<3.32 to 17.19 ± 5.24	<3.13 to 10.8 ± 4.98	PZ-106-SD
Gross Alpha (Total)	3.51 ± 2.69 to 28.8 ± 7.21	<4.18 to 12.3 ± 5.4	PZ-106-SD
Gross Beta (Dissolved)	<3.72 to 9.28 ± 3.86	<4.14 to 6.73 ± 2.19	PZ-100-SD
Gross Beta (Total)	4.37 ± 2.25 to 20.5 ± 4.37	<3.56 to 9.53 ± 3.61	MW-1204
Radium-226 (Dissolved)	<0.43 to 1.42 ± 0.563	<0.706 to 2.38 ± 0.729	MW-1204
Radium-226 (Total)	0.78 ± 0.09 to 3.33 ± 0.769	<0.678 to 2.98 ± 0.898	PZ-100-SD
Uranium-234 (Dissolved)	0.89 ± 0.28 to 8.2 ± 1.37	<0.283 to 2.32 ± 0.541	PZ-106-SD
Uranium-234 (Total)	0.80 ± 0.26 to 9.78 ± 1.81	<0.628 to 15.3 ± 1.82	MW-1204
Uranium-235/236 (Dissolved)	<0.141 to 0.769 ± 0.449	<0.13 to 0.315 ± 0.176	PZ-100-SD
Uranium-235/236 (Total)	<0.169 to 0.516 ± 0.35	<0.159 to 0.744 ± 0.416	MW-1204
Uranium-238 (Dissolved)	0.50 ± 0.20 to 3.36 ± 0.888	<0.283 to 2.57 ± 1.14	PZ-106-SD
Uranium-238 (Total)	0.25 ± 0.13 to 4.55 ± 1.25	<0.346 to 6.9 ± 1.2	MW-1204
Thorium-230 (Dissolved)	<0.502 to 0.29 ± 0.17	<0.283 to 1.05 ± 0.326	PZ-100-SD
Thorium-230 (Total)	<0.736 to 0.84 ± 0.29	<0.473 to 0.845 ± 0.288	PZ-100-SD

Note: Background data from PZ-300-SS, PZ-301-SS, PZ-204A-SS

Table 4-11. Volatile organic compounds (mg/l) in PZ-303-AS, PZ-304-AS, and PZ-304-AI

Compounds	Round 1			Round 2		
	PZ-303-AS	PZ-304-AS	PZ-304-AI	PZ-303-AS	PZ-304-AS	PZ-304-AI
Acetone	***0.009***	<0.005	<0.005	<0.005	<0.005	<0.005
Benzene	***0.078***	***0.005***	***0.01***	***0.078***	***0.0062***	***0.011***
Chlorobenzene	<0.002	***0.008***	<0.002	<0.002	***0.0087***	<0.002
Chloroethane	***0.013***	<0.002	<0.002	***0.011***	<0.002	<0.002
1,2-Dichloroethane	***0.002***	<0.002	<0.002	<0.002	<0.002	<0.002
1,2-Dichlorobenzene	<0.002	<0.002	<0.002	***0.0038***	<0.002	<0.002
1,4-Dichlorobenzene	<0.002	***0.012***	***0.003***	***0.0034***	***0.012***	***0.0033***
1,1-Dichloroethane	<0.002	***0.002***	<0.002	***0.033***	<0.002	<0.002
1,1-Dichloroethylene	<0.002	<0.002	<0.002	<0.002	***0.003***	<0.002
1,2-cis-Dichloroethylene	***0.008***	***0.006***	***0.011***	***0.0081***	***0.0067***	***0.013***
1,2-trans-Dichloroethylene	***0.002***	<0.002	<0.002	***0.0025***	<0.002	<0.002
Ethylbenzene	***0.12***	<0.002	<0.002	***0.113***	<0.002	<0.002
Methyl Ethyl Ketone	***0.007***	<0.002	<0.002	<0.005	<0.005	<0.005
Styrene	***0.006***	<0.002	<0.002	<0.002	<0.002	<0.002
Toluene	***0.4***	<0.002	<0.002	***0.38***	<0.002	<0.002
Vinyl Chloride	***0.012***	***0.012***	***0.01***	***0.026***	***0.0076***	***0.0062***
Total Xylenes	***0.67***	<0.002	<0.002	***0.53***	<0.002	<0.002

Table 4-12. Comparison of alluvial detection results to background alluvial groundwater quality

Parameter	Range of background concentrations (mg/l)	Range of detection results (mg/l)	Piezometer exhibiting maximum detection concentration
Antimony (Dissolved)	<0.003 to <0.003	<0.003 to <0.003	
Antimony (Total)	<0.003 to <0.003	<0.003 to 0.004	PZ-113-AD
Arsenic (Dissolved)	0.004 to 0.004	<0.002 to 0.094	PZ-304-AS
Arsenic (Total)	0.004 to 0.004	<0.002 to 0.087	PZ-303-AS
Barium (Dissolved)	0.152 to 0.178	0.089 to 1.24	PZ-304-AS
Barium (Total)	0.152 to 0.182	0.091 to 1.23	PZ-304-AS
Beryllium (Dissolved)	<0.001 to <0.001	<0.001 to <0.001	
Beryllium (Total)	<0.001 to <0.001	<0.001 to <0.001	
Boron (Dissolved)	<0.1 to <0.1	<0.1 to 0.831	PZ-304-AS
Boron (Total)	<0.1 to <0.1	<0.1 to 0.847	PZ-304-AS
Cadmium (Dissolved)	<0.005 to <0.005	<0.005 to <0.005	
Cadmium (Total)	<0.005 to <0.005	<0.005 to <0.005	
Calcium (Dissolved)	158 to 159	112 to 300	PZ-303-AS
Calcium (Total)	131 to 176	103 to 290	PZ-303-AS
Chromium (Dissolved)	<0.010 to <0.010	<0.010 to <0.010	
Chromium (Total)	<0.010 to 0.011	<0.010 to 0.017	PZ-303-AS
Cobalt (Dissolved)	<0.020 to <0.020	<0.020 to <0.020	
Cobalt (Total)	<0.020 to <0.020	<0.020 to <0.020	
Copper (Dissolved)	<0.020 to <0.020	<0.020 to <0.020	
Copper (Total)	<0.020 to <0.020	<0.020 to <0.020	
Iron (Dissolved)	3.33 to 4.06	<0.04 to 92	PZ-303-AS
Iron (Total)	1.98 to 2.83	0.063 to 90.1	PZ-303-AS
Lead (Dissolved)	<0.002 to <0.002	<0.002 to <0.002	
Lead (Total)	<0.002 to <0.002	<0.002 to <0.002	
Magnesium (Dissolved)	56.4 to 58.0	38.3 to 89.0	PZ-303-AS
Magnesium (Total)	41.6 to 57.8	39.8 to 84.3	PZ-303-AS
Manganese (Dissolved)	3.09 to 3.32	0.017 to 6.54	PZ-303-AS
Manganese (Total)	3.05 to 3.14	0.077 to 6.39	PZ-113-AS
Mercury (Dissolved)	<0.0002 to <0.0002	<0.0002 to <0.0002	
Mercury (Total)	<0.0002 to <0.0002	<0.0002 to <0.0002	
Nickel (Dissolved)	<0.04 to <0.04	<0.04 to 0.04	PZ-304-AS
Nickel (Total)	<0.04 to <0.04	<0.04 to 0.044	PZ-304-AS
Selenium (Dissolved)	<0.002 to <0.002	<0.002 to 0.024	MW-103
Selenium (Total)	<0.002 to <0.002	<0.002 to 0.018	MW-103
Silver (Dissolved)	<0.010 to <0.010	<0.010 to <0.010	
Silver (Total)	<0.010 to <0.010	<0.010 to <0.010	
Sodium (Dissolved)	43.4 to 44.9	12.5 to 197	PZ-304-AS
Sodium (Total)	35.4 to 73.0	12.8 to 206	PZ-304-AS
Thallium (Dissolved)	<0.002 to <0.002	<0.002 to <0.002	
Thallium (Total)	<0.002 to <0.002	<0.002 to <0.002	
Vanadium (Dissolved)	<0.010 to <0.010	<0.010 to <0.010	
Vanadium (Total)	<0.010 to <0.010	<0.010 to <0.010	
Zinc (Dissolved)	<0.030 to <0.030	<0.030 to <0.030	
Zinc (Total)	<0.030 to <0.030	<0.030 to 0.056	PZ-113-AS

Table 4-12. Comparison of alluvial detection results to background alluvial groundwater quality (continued)

Parameter	Range of background concentrations	Range of detection results	Piezometer exhibiting maximum detection concentration
Conventionals (mg/l)			
Ammonia as N	0.4 to 0.4	<0.1 to 56.1	PZ-304-AS
Chemical Oxygen Demand	<15 to 40	<15 to 108	PZ-303-AS
Chloride	130 to 215	17 to 299	PZ-304-AS
Cyanide, Total	<0.010 to <0.010	<0.010 to <0.010	
Fluoride	0.27 to 0.36	<0.25 to 0.73	PZ-304-AS
Hardness, Total	660 to 700	470 to 1100	PZ-303-AS
Nitrate/Nitrite	<0.1 to <0.1	<0.1 to 0.3	MW-103
Phosphorus, Total	0.39 to 0.63	<0.01 to 1.5	PZ-303-AS
Sulfate, as SO_4	62 to 110	<2 to 67	MW-103
Sulfide as S	<1 to <1	<1 to 1	MW-103
Total Dissolved Solids	933 to 940	86 to 1396	PZ-303-AS
Total Organic Carbon	2 to 3	3 to 30	PZ-304-AS
Radionuclides (pCi/l)			
Gross Alpha (Dissolved)	<3.03 to <8.19	<6.22 to 9.83 ± 3.22	MW-103
Gross Alpha (Total)	<3.53 to 56.1 ± 9.5	<7.27 to 9.61 ± 6.23	PZ-304-AI
Gross Beta (Dissolved)	<3.94 to 6.02 ± 3.00	9.2 ± 2.12 to 49.2 ± 8.33	PZ-304-AS
Gross Beta (Total)	4.38 ± 2.49 to 53.1 ± 6.2	<7.21 to 49.5 ± 7.24	PZ-304-AS
Radium-226 (Dissolved)	0.069 ± 0.029 to 0.35 ± 0.05	<0.415 to 1.39 ± 0.6	PZ-113-AD
Radium-226 (Total)	<0.066 to 0.51 ± 0.7	<0.419 to 2.31 ± 0.803	PZ-113-AD
Uranium-234 (Dissolved)	0.25 ± 0.13 to 0.88 ± 0.26	<0.275 to 3.71 ± 0.969	MW-103
Uranium-234 (Total)	0.32 ± 0.15 to 0.99 ± 0.31	<0.261 to 4.18 ± 1	MW-103
Uranium-235/236 (Dissolved)	<0.10 to 0.16 ± 0.11	<0.139 to <0.595	PZ-303-AS
Uranium-235/236 (Total)	<0.09 to 0.27 ± 0.17	<0.136 to <0.623	PZ-304-AI
Uranium-238 (Dissolved)	<0.097 to 0.63 ± 0.21	<0.139 to 4.17 ± 0.969	MW-103
Uranium-238 (Total)	<0.258 to 1.19 ± 0.35	<0.155 to 3.67 ± 0.906	MW-103
Thorium-230 (Dissolved)	<0.627 to 0.93 ± 0.30	<0.523 to 0.964 ± 0.435	PZ-304-AI
Thorium-230 (Total)	<0.415 to 1.48 ± 0.40	<0.447 to 1.21 ± 0.374	PZ-304-AS

Table 4-13. Organic compounds in cluster piezometers PZ-304-AS and PZ-304-AI

Compounds	Round 1 (mg/l)		Round 2 (mg/l)	
	PZ-304-AS	PZ-304-AI	PZ-304-AS	PZ-304-AI
Benzene	***0.005***	***0.01***	***0.0062***	***0.011***
Chlorobenzene	***0.008***	<0.002	***0.0087***	<0.002
1,4- Dichlorobenzene	***0.012***	***0.003***	***0.012***	***0.0033***
1,1-Dichloroethane	***0.002***	<0.002	<0.002	<0.002
1,1-Dichloroethylene	<0.002	<0.002	***0.003***	<0.002
1,2-cis-Dichloroethylene	***0.006***	***0.011***	***0.0067***	***0.013***
Vinyl Chloride	***0.012***	***0.01***	***0.0076***	***0.0062***

Notes:

No semi-volatile organics, pesticides or PCBs were detected.

All detected organic compounds are landfill gas constituents.

Table 4-14. Priority Pollutant Metals Summary for Groundwater Samples: Operable Unit 1

Constituent	Sampling Date	Type of Sample	Number of Samples	Number of Detections	Frequency Detection	Minimum Detection Value (mg/l)	Maximum Detection Value (mg/l)	Sample Exhibiting Maximum Value
Arsenic	Nov-95	Unfiltered	33	14	42%	0.018	0.420	MW-F3
		Filtered	33	13	39%	0.011	0.400	MW-F3
	Feb-96	Filtered	33	12	36%	0.010	0.260	MW-F3
Chromium	Nov-95	Unfiltered	33	9	27%	0.010	0.062	S-80
		Filtered	33	1	3%	0.011	0.011	S-10
	Feb-96	Filtered	33	2	6%	0.015	0.022	S-5
Copper	Nov-95	Unfiltered	33	6	18%	0.023	0.076	S-80
		Filtered	33	0	0%	0	0	No Detects
	Feb-96	Filtered	33	0	0%	0	0	No Detects
Lead	Nov-95	Unfiltered	33	23	70%	0.0031	0.070	MW-F3
		Filtered	33	1	3%	0.0041	0.0041	I-4
	Feb-96	Filtered	33	1	3%	0.0079	0.0079	S-5
Nickel	Nov-95	Unfiltered	33	9	27%	0.023	0.093	S-5
		Filtered	33	5	15%	0.021	0.099	S-5
	Feb-96	Filtered	33	4	12%	0.020	0.110	S-5
Zinc	Nov-95	Unfiltered	33	19	58%	0.022	0.330	D-14
		Filtered	33	3	9%	0.028	0.077	D-83
	Feb-96	Filtered	33	4	12%	0.020	0.049	I-11

Source:
April 7, 2000 "Remedial Investigation Report, West Lake Operable Unit 1," Engineering Management Support, Inc.

Table 4-15. Total Petroleum Hydrocarbons Summary for Groundwater Samples: Operable Unit 1

Constituent	Sampling Date	Number of Samples	Number of Detections	Frequency Detection	Minimum Detection Value (mg/l)	Maximum Detection Value (mg/l)	Sample Exhibiting Maximum Value
Diesel Range	Nov-95	33	3	9%	0.59	3.5	S-5
	Feb-96	33	1	3%	0.53	0.53	D-14
Motor Oil Range	Nov-95	33	3	9%	0.65	2.3	I-11
	Feb-96	33	0	0%	0	0	No Detects

Source:
April 7, 2000 "Remedial Investigation Report, West Lake Operable Unit 1," Engineering Management Support, Inc.

Table 4-16. Volatile Organic Compounds Summary for Groundwater Samples: Operable Unit 1

Constituent	Sampling Date	Number of Samples	Number of Detections	Frequency Detection	Minimum Detection Value (mg/l)	Maximum Detection Value (mg/l)	Sample Exhibiting Maximum Value
Benzene	Nov-95	33	2	6%	0.0093	0.011	I-2
	Feb-96	33	4	12%	0.0056	0.0074	I-9
Chlorobenzene	Nov-95	33	5	15%	0.0053	0.170	D-14
	Feb-96	33	4	12%	0.0096	0.150	D-14
1,4-Dichlorobenzene	Nov-95	33	3	9%	0.012	0.050	D-14
	Feb-96	33	3	9%	0.0099	0.046	D-14
cis-1,2-Dichloroethane	Nov-95	33	3	9%	0.0072	0.026	S-82
	Feb-96	33	3	9%	0.0086	0.034	S-82
Acetone	Nov-95	33	3	9%	0.037	0.068	D-12
	Feb-96	33	0	0%	0	0	No Detects

Source:
April 7, 2000 "Remedial Investigation Report, West Lake Operable Unit 1," Engineering Management Support, Inc.

Table 4-17. Semi-Volatile Organic Compounds Summary for Groundwater Samples: Operable Unit 1

Constituent	Sampling Date	Number of Samples	Number of Detections	Frequency Detection	Minimum Detection Value (mg/l)	Maximum Detection Value (mg/l)	Sample Exhibiting Maximum Value
1,4-Dichlorobenzene	Nov-95	33	2	6%	0.012	0.018	D-14
	Feb-96	33	1	3%	0.038	0.038	D-14
4-Methylphenol	Nov-95	33	2	6%	0.067	0.290	I-11
	Feb-96	33	0	0%	0	0.000	No Detects
Di-n-octylphthalate	Nov-95	33	1	3%	0.013	0.013	I-62
	Feb-96	33	0	0%	0	0	No Detects
Bis(2-Ethylhexyl) phthalate	Nov-95	33	0	0%	0	0	No Detects
	Feb-96	33	0	0%	0	0	No Detects

Source:
April 7, 2000 "Remedial Investigation Report, West Lake Operable Unit 1," Engineering Management Support, Inc.

Table 4-18. Pesticides and Polychlorinated Biphenyls Summary for Groundwater Samples: Operable Unit 1

Constituent	Sampling Date	Number of Samples	Number of Detections	Frequency Detection	Minimum Detection Value (mg/l)	Maximum Detection Value (mg/l)	Sample Exhibiting Maximum Value
4,4'-DDD	Nov-95	33	1	3%	0.00011	0.00011	S-5
	Feb-96	33	0	0%	0	0	No Detects
Aldrin	Nov-95	33	1	3%	0.00002	0.00002	D-6
	Feb-96	33	0	0%	0	0	No Detects
gamma-BHC (Lindane)	Nov-95	33	1	3%	0.000011	0.000011	D-85
	Feb-96	33	0	0%	0	0	No Detects

Source:
April 7, 2000 "Remedial Investigation Report, West Lake Operable Unit 1," Engineering Management Support, Inc.

Table 4-19. Total organic carbon results – piezometer, leachate riser, and solid gas probe soil samples

Sample Location	Total organic carbon (mg/kg)
PZ-300-AS (16.0 – 16.5 ft)	4,600
PZ-300-AD (40.5 – 41.0 ft)	420
PZ-302-AS (17.5 - 18.0 ft)	240
PZ-302-AI (35.5 - 36.0 ft)	360
PZ-304-AS (23.5 – 24 ft)	420
PZ-304-AI (35.5 – 36.0 ft)	360
PZ-305-AI (50 – 52 ft)	360
LR-103 (32.5 – 33 ft)	20,000
LR-104 (30.5 – 31 ft)	480
SG-01 (3.5 ft)	8,500
SG-02 (3.5 ft)	3,900
SG-03 (3.5 ft)	3,100
SG-04 (3.5 ft)	4,500
SG-05 (3.5 ft)	4,200
SG-06 (3.5 ft)	6,900
SG-07 (3.5 ft)	2,300
SG-08 (3.5 ft)	2,600
SG-09 (3.5 ft)	10,000
SG-10 (3.5 ft)	5,900

Table 4-20. Alluvial soil total petroleum hydrocarbon and VOC results – Piezometer PZ-300-AS; soil borings SB-01 through SB-04

Sampling Location	TPH Purgeable-range (mg/kg)	TPH Extractable-range (mg/kg)	VOCs (mg/kg)
PZ-303-AS (17 ft)	2,000	12,000	Toluene (5.3) Ethylbenzene (10) Total Xylenes (54)
PZ-303-AS (20 – 25.5 ft)	160	160	Total Xylenes (0.82)
SB-01 (16 – 18 ft)	6,700	15,000	Toluene (310) Ethylbenzene (24) Total Xylenes (120)
SB-02 (4 – 6 ft)	<0.1	32	ND
SB-02 (14 – 16 ft)	<0.1	24	ND
SB-03 (6 – 8 ft)	<0.1	23	ND
SB-03 (10 – 12 ft)	<0.1	<10	ND
SB-04 (8 – 10 ft)	<0.1	<10	ND

ND: None detected

Table 4-21. Organic compounds detected in leachate

Compound	Active Sanitary Landfill (mg/l)			
	LCS-1	LCS-2	LCS-3	LCS-4
Acetone	***1.2***	***0.65***	***0.038***	***61***
Benzene	<0.5	***0.009***	<0.005	<0.005
Chlorobenzene	<0.5	***0.035***	***0.029***	***0.011***
1,4-Dichlorobenzene	<0.5	***0.081***	***0.009***	***0.056***
Ethylbenzene	<0.5	***0.0.49***	***0.023***	***0.07***
2-Hexanone	<1	***0.1***	<0.010	***0.18***
Methyl Ethyl Ketone	***3***	***1.3***	***0.11***	***2.6***
Methyl iso-butyl Ketone	<1	***0.08***	<0.010	***0.076***
Styrene	<0.5	***0.005***	<0.005	***0.006***
Toluene	<0.5	***0.097***	***0.015***	***0.12***
Total Xylenes	<0.5	***0.14***	***0.035***	***0.17***
m+p Cresol	***1.9***	***0.95***	***0.077***	***0.26***
2,4-Dimethylphenol	<0.010	<0.010	<0.010	<0.010
Bis(2-ethylhexyl_phthalate	***0.019***	***0.22***	***0.017***	<0.010
Diethyl phthalate	***0.033***	<0.010	<0.010	<0.010
Dimethyl phthalate	***0.012***	<0.010	<0.010	<0.010
Phenol	***0.29***	***0.16***	<0.010	***0.017***
Naphthalene	<0.010	<0.010	<0.010	<0.010
Volatile Petroleum Hydrocarbons	***0.41***	***0.4***	***0.12***	***0.48***
Diesel-range Petroleum Hydrocarbons	***79***	***6.9***	***2.2***	***0.22***
Compound	**Inactive Sanitary Landfill (mg/l)**			
	LR-100	**LR-103**	**LR-104**	**LR-105**
Acetone	<0.010	<0.010	<0.010	***0.04***
Benzene	<0.005	<0.005	<0.005	***0.007***
Chlorobenzene	***0.044***	<0.005	<0.005	***0.74***
1,4-Dichlorobenzene	***0.01***	<0.005	<0.005	***0.068***
Ethylbenzene	***0.012***	<0.005	<0.005	***0.089***
2-Hexanone	<0.010	<0.010	<0.010	<0.010
Methyl Ethyl Ketone	<0.010	<0.010	<0.010	<0.010
Methyl iso-butyl Ketone	<0.010	<0.010	<0.010	<0.010
Styrene	<0.005	<0.005	<0.005	<0.005
Toluene	<0.005	<0.005	<0.005	***0.007***
Total Xylenes	***0.057***	<0.005	<0.005	***0.43***
m+p Cresol	<0.010	<0.010	<0.010	R
2,4-Dimethylphenol	<0.010	<0.010	<0.010	***0.082***
Bis(2-ethylhexyl)phthalate	***0.12***	<0.006	<0.006	***0.36***
Diethyl phthalate	<0.010	<0.010	<0.010	<0.010
Dimethyl phthalate	<0.010	<0.010	<0.010	<0.010
Phenol	<0.010	<0.010	<0.010	R
Naphthalene	0.011	<0.010	<0.010	<0.010
Volatile Petroleum Hydrocarbons	***0.17***	<0.005	<0.005	***0.95***
Diesel-range Petroleum Hydrocarbons	***2.2***	***0.63***	***0.08***	***4.4***

Notes:

R: Data point rejected during data validation

Inactive landfill leachate riser LR-101 was not installed due to the absence of leachate in this location.

Inactive landfill leachate riser LR-102 was not sampled due to minimal (<6 inches) liquid thickness.

Table 4-22. Soil gas screening results, West Lake Landfill

Location	PID (ppm)	Percent Oxygen	Percent lower explosive limit	Hydrogen sulfide (ppm)
SG-01	0	20.8	0	0
SG-02	0	18.9	0	0
SG-03	7.6	14.4	2	0
SG-04	0	18.7	0	0
SG-05	10.1	18.3	0	0
SG-06	0	20.6	0	0
SG-07	0	20.7	0	0
SG-08	0	18.8	130	0
SG-09	0	14	0	0
SG-10	0	18.9	0	0

Table 4-23. Inactive landfill gas concentrations versus typical municipal solid waste landfill gas constituents

Detected compound	Typical landfill gas constituents*		Inactive landfill gas	
	Mean Result (ppmV)	Maximum Result (ppmV)	Result (ppmV)	Location
Acetone	6.838	240	24	LG-05
Benzene	2.057	39	0.41	LG-08
Chlorobenzene	0.082	1.64	1.1	LG-05
Chloroform	0.245	12		
1,1-Dichloroethane	2.801	36		
Dichloromethane	25.694	620		
1,1-Dichloroethene	0.13	4		
Diethylene chloride	2.835	20		
1,2-trans-Dichloroethane	0.036	0.85		
Ethyl benzene	7.334	87.5	0.24	LG-10
Methyl Ethyl Ketone	3.092	130	0.18	LG-08
1,1,1-Trichloroethane	0.615	14.5		
Trichloroethylene	2.079	32		
Toluene	34.907	280	1.2	LG-01
1,2,2 Tetrachloroethane	0.246	16		
Tetrachloroethane	5.244	180		
Vinyl Chloride	3.508	32	0.74	LG-08
Styrenes	1.517	87		
Vinyl Acetate	5.663	240		
Xylenes	2.651	38	0.91	LG-10
Chloroethane			0.25	LG-01
4 Ethyl Toluene			0.046	LG-10
Freon 11			0.02	LG-10
Freon-12			0.78	LG-09
Freon 114			0.52	LG-08
Methylene chloride			0.061	LG-07
1,4-Dichlorobenzene			0.066	LG-05
1,2,4-Trimethylbenzene			0.26	LG-05
1,3,5-Trimethylbenzene			0.068	LG-05
1,2-cis-Dichloroethylene			0.0071	LG-04
Carbon disulfide			0.13	LG-01

* Source: Tchobanoglous, et al, 1993.

Table 5-1. Summary of environmental samples collected during the West Lake Landfill Operable Unit 2 RI/FS

Date	Medium	Laboratory	Number of primary environmental samples	Number and Type of Quality Assurance Samples
1995	Groundwater	Quanterra Laboratory	4	None
	Soil	Quanterra Laboratory	17	4 Matrix Spikes 4 Matrix Spike Duplicates
	Drilling Water	Quanterra Laboratory	1	1 Trip Blank 1 Matrix Spike 1 Matrix Spike Duplicate
1997	Groundwater	PACE Analytical Services	48 (2 rounds from 24 wells	6 Field Duplicates 6 Field Blanks 6 Equipment Blanks 7 Matrix Spikes 7 Matrix Spike Duplicates
		TriMatrix Laboratories	6 (2 rounds from 3 wells)	2 Field Duplicates 2 Matrix Spikes 2 Matrix Spike Duplicates
		Southwest Laboratory of Oklahoma	48 (2 rounds from 24 wells)	6 Field Duplicates 6 Field Blanks 6 Equipment Blanks
		Paragon Analytics	6 (2 rounds from 3 wells)	2 Field Duplicates
	Leachate	PACE Analytical Services	8	1 Field Duplicate 1 Field Blank 1 Matrix Spike 1 Matrix Spike Duplicate
		TriMatrix Laboratories	2	1 Matrix Spike 1 Matrix Spike Duplicate
		Southwest Laboratory of Oklahoma	8	1 Field Duplicate 1 Field Blank
		Paragon Analytics	2	
	Surface Water	PACE Analytical Services	2	1 Field Duplicate 1 Field Blank 1 Matrix Spike 1 Matrix Spike Duplicate
		TriMatrix Laboratories	1	1 Matrix Spike 1 Matrix Spike Duplicate
		Southwest Laboratory of Oklahoma	2	1 Field Duplicate 1 Field Blank
	Sediments	PACE Analytical Services	2	1 Field Duplicate
		TriMatrix Laboratories	1	
	Soil	PACE Analytical Services	10	1 Field Duplicate 2 Matrix Spikes
	Air	Air Toxics	11	1 Field Duplicate

Table 6-1. Summary of Detected Parameters Which Exceed MCLs or MCLGs in Groundwater

Parameter	Range of Detections	Piezometer Exhibiting the Maximum Detection Concentration	PRG	Exceed (Y/N)	MCL	Exceed (Y/N)	COPC (Y/N)
Alluvium							
Metals	**(mg/l)**		**(mg/l)**				
Arsenic (Dissolved)	<0.002 to 0.094	PZ-304-AS	0.000045	Y	0.05 [a]	Y	Y
Arsenic (Total)	<0.002 to 0.087	PZ-303-AS	0.000045	Y	0.05 [a]	Y	Y
Iron (Dissolved)	<0.04 to 92	PZ-303-AS	11	Y	0.3 [b]	Y	Y
Iron (Total)	0.063 to 90.1	PZ-303-AS	11	Y	0.3 [b]	Y	Y
Manganese (Dissolved)	0.017 to 6.54	PZ-113-AS	0.88	Y	0.05 [b]	Y	Y
Manganese (Total)	0.077 to 6.39	PZ-113-AS	0.88	Y	0.05 [b]	Y	Y
Conventionals	**(mg/l)**		**(mg/l)**				
Chloride	17 to 299	PZ-304-AS	NA	NA	250 [b]	Y	Y
Total Dissolved Solids	86 to 1396	PZ-303-AS	NA	NA	500 [b]	Y	Y
Volatile Organics	**(mg/l)**		**(mg/l)**				
Benzene	<0.002 to 0.078	PZ-303-AS	0.00041	Y	0.005 [a]	Y	Y
Vinyl Chloride	<0.001 to 0.026	PZ-303-AS	0.00002	Y	0.002 [a]	Y	Y
Total Petroleum Hydrocarbons	13.12 to 21.3	PZ-303-AS	NA	NA	10 [d]	Y	Y
St. Louis/Upper Salem							
Metals	**(mg/l)**		**(mg/l)**				
Iron (Dissolved)	<0.04 to 4.24	PZ-110-SS	11	N	0.3 [b]	Y	Y
Iron (Total)	<0.04 to 5.87	PZ-110-SS	11	N	0.3 [b]	Y	Y
Manganese (Dissolved)	<0.01 to 0.375	PZ-201A-SS	0.88	N	0.05 [b]	Y	Y
Manganese (Total)	0.017 to 0.528	PZ-201A-SS	0.88	N	0.05 [b]	Y	Y
Conventionals	**(mg/l)**		**(mg/l)**				
Fluoride	0.49 to 2.7	PZ-113-SS	2.2	Y	2 [b]	Y	Y
Total Dissolved Solids	364 to 1418	PZ-110-SS	NA	NA	500 [c]	Y	Y

Table 6-1. Summary of Detected Parameters Which Exceed MCLs or MCLGs in Groundwater

Parameter	Range of Detections	Piezometer Exhibiting the Maximum Detection Concentration	PRG	Exceed (Y/N)	MCL	Exceed (Y/N)	COPC (Y/N)
Deep Salem							
Metals	**(mg/l)**		**(mg/l)**				
Iron (Dissolved)	<0.04 to 0.945	MW-1204	11	N	0.3 [b]	Y	Y
Iron (Total)	0.119 to 2.09	PZ-100-AD	11	N	0.3 [b]	Y	Y
Manganese (Dissolved)	0.016 to 2.09	PZ-106-SD	0.88	N	0.05 [b]	Y	Y
Manganese (Total)	0.017 to 0.332	PZ-100-SD	0.88	N	0.05 [b]	Y	Y
Conventionals	**(mg/l)**		**(mg/l)**				
Total Dissolved Solids	340 to 665	PZ-106-SD	NA	NA	500 [b]	Y	Y

[a] Primary MCL 40 CFR 141.11 and 141.62

[b] Secondary MCL 40 CFR 143.3

[c] MCLG 40 CFR 141.51

[d] Missouri Department of Natural Resources Division of Environmental Quality, Sept. 1998, Appendix B Tier 1 Clean-up Levels.

[e] One detect only

PRGs cited from Region IX Preliminary Remediation Goals (PRGs), United States Environmental Protection Agency, October 1, 1999

Table 6-2. Summary of Detected Parameters from Alluvial Groundwater Sampling

Parameter	Range of background concentrations	Range of detection results	Frequency of Detection	Piezometer exhibiting maximum detection concentration
Metals				
Antimony (Total)	<0.003 to <0.003	<0.003 to 0.004	1/19	PZ-113-AD
Arsenic (Dissolved)	0.004 to 0.004	<0.002 to 0.094	13/19	PZ-304-AS
Arsenic (Total)	0.004 to 0.004	<0.002 to 0.087	15/19	PZ-303-AS
Barium (Dissolved)	0.152 to 0.178	0.089 to 1.24	19/19	PZ-304-AS
Barium (Total)	0.152 to 0.182	0.091 to 1.23	19/19	PZ-304-AS
Boron (Dissolved)	<0.1 to <0.1	<0.1 to 0.831	13/19	PZ-304-AS
Boron (Total)	<0.1 to <0.1	<0.1 to 0.847	13/19	PZ-304-AS
Calcium (Dissolved)	158 to 159	112 to 300	19/19	PZ-303-AS
Calcium (Total)	131 to 176	103 to 290	24/24	PZ-303-AS
Chromium (Total)	<0.010 to 0.011	<0.010 to 0.017	3/19	PZ-303-AS
Iron (Dissolved)	3.33 to 4.06	<0.04 to 92	18/19	PZ-303-AS
Iron (Total)	1.98 to 2.83	0.063 to 90.1	19/19	PZ-303-AS
Magnesium (Dissolved)	56.4 to 58.0	38.3 to 89.0	19/19	PZ-303-AS
Magnesium (Total)	41.6 to 57.8	39.8 to 84.3	24/24	PZ-303-AS
Manganese (Dissolved)	3.09 to 3.32	0.017 to 6.54	19/19	PZ-303-AS
Manganese (Total)	3.05 to 3.14	0.077 to 6.39	19/19	PZ-113-AS
Nickel (Dissolved)	<0.04 to <0.04	<0.04 to 0.04	1/19	PZ-304-AS
Nickel (Total)	<0.04 to <0.04	<0.04 to 0.044	2/19	PZ-304-AS
Selenium (Dissolved)	<0.002 to <0.002	<0.002 to 0.024	1/19	MW-103
Selenium (Total)	<0.002 to <0.002	<0.002 to 0.018	2/19	MW-103
Sodium (Dissolved)	43.4 to 44.9	12.5 to 197	19/19	PZ-304-AS
Sodium (Total)	35.4 to 73.0	12.8 to 206	24/24	PZ-304-AS
Zinc (Total)	<0.030 to <0.030	<0.030 to 0.056	2/19	PZ-113-AS
Conventionals (mg/l)				
Ammonia as N	0.4 to 0.4	<0.1 to 56.1	18/19	PZ-304-AS
Chemical Oxygen Demand	<15 to 40	<15 to 108	14/24	PZ-303-AS
Chloride	130 to 215	17 to 299	24/24	PZ-304-AS
Fluoride	0.27 to 0.36	<0.25 to 0.73	14/19	PZ-304-AS
Hardness, Total	660 to 700	470 to 1100	19/19	PZ-303-AS
Nitrate/Nitrite	<0.1 to <0.1	<0.1 to 0.3	NR	MW-103
Phosphorus, Total	0.39 to 0.63	<0.01 to 1.5	19/19	PZ-303-AS
Sulfate, as SO4	62 to 110	<2 to 67	22/24	MW-103
Sulfide as S	<1 to <1	<1 to 1	5/19	MW-103
Total Dissolved Solids	933 to 940	86 to 1396	19/19	PZ-303-AS
Total Organic Carbon	2 to 3	3 to 30	23/23	PZ-304-AS
Radionuclides (pCi/l)				
Gross Alpha (Dissolved)	<3.03 to <8.19	<6.22 to 9.83 ± 3.22	1/23	MW-103
Gross Alpha (Total)	<3.53 to 56.1 ± 9.5	<7.27 to 9.61 ± 6.23	4/22	PZ-304-AI
Gross Beta (Dissolved)	<3.94 to 6.02 ± 3.00	9.2 ± 2.12 to 49.2 ± 8.33	18/24	PZ-304-AS
Gross Beta (Total)	4.38 ± 2.49 to 53.1 ± 6.2	<7.21 to 49.5 ± 7.24	19/24	PZ-304-AS
Radium-226 (Dissolved)	0.069 ± 0.029 to 0.35 ± 0.05	<0.415 to 1.39 ± 0.6	23/24	PZ-113-AD
Radium-226 (Total)	<0.066 to 0.51 ± 0.7	<0.419 to 2.31 ± 0.803	18/23	PZ-113-AD
Uranium-234 (Dissolved)	0.25 ± 0.13 to 0.88 ± 0.26	<0.275 to 3.71 ± 0.969	14/21	MW-103
Uranium-234 (Total)	0.32 ± 0.15 to 0.99 ± 0.31	<0.261 to 4.18 ± 1	17/23	MW-103
Uranium-235/236 (Dissolved)	<0.10 to 0.16 ± 0.11	<0.139 to <0.595	1/15	PZ-303-AS
Uranium-235/236 (Total)	<0.09 to 0.27 ± 0.17	<0.136 to <0.623	2/15	PZ-304-AI
Uranium-238 (Dissolved)	<0.097 to 0.63 ± 0.21	<0.139 to 4.17 ± 0.969	14/21	MW-103
Uranium-238 (Total)	<0.258 to 1.19 ± 0.35	<0.155 to 3.67 ± 0.906	17/21	MW-103
Thorium-230 (Dissolved)	<0.627 to 0.93 ± 0.30	<0.523 to 0.964 ± 0.435	10/22	PZ-304-AI
Thorium-230 (Total)	<0.415 to 1.48 ± 0.40	<0.447 to 1.21 ± 0.374	11/23	PZ-304-AS

Table 6-2. Summary of Detected Parameters from Alluvial Groundwater Sampling (continued)

Parameter	Range of background concentrations	Range of detection results	Frequency of Detection	Piezometer exhibiting maximum detection concentration
Volatiles/Organics				
1,1-Dichloroethane	<0.002 to <0.002	<0.002 to 0.033	4/21	PZ-303-AS
1,1-Dichloroethylene	<0.002 to <0.002	<0.002 to 0.003	1/21	PZ-304-AS
1,2-cis-Dichloroethylene	0.004 to 0.0044	<0.002 to 0.013	10/19	PZ-304-AI
1,2-Dichlorobenzene	<0.002 to <0.002	<0.002 to 0.0038	1/19	PZ-303-AS
1,2-Dichloroethane	<0.002 to <0.002	<0.002 to 0.002	1/21	PZ-303-AS
1,2-trans-Dichloroethylene	<0.002 to <0.002	<0.002 to 0.0025	2/19	PZ-303-AS
1,4-Dichlorobenzene	<0.002 to <0.002	<0.002 to 0.012	7/19	PZ-304-AS
2,4-Dimethylphenol	<0.01 to <0.01	<0.01 to 0.086	2/19	PZ-303-AS
2-Methylnaphthalene	<0.01 to <0.01	<0.01 to 0.015	1/19	PZ-303-AS
Acetone	<0.005 to <0.005	<0.005 to 0.009	1/21	PZ-303-AS
Benzene	<0.002 to <0.002	<0.002 to 0.078	8/21	PZ-303-AS
bis(2-Ethylhexl)phthalate	<0.006 to <0.006	<0.006 to 0.046	1/19	PZ-103-D (MW-103)
Chlorobenzene	<0.002 to <0.002	<0.002 to 0.0087	4/21	PZ-304-AS
Chloroethane	<0.002 to <0.002	<0.002 to 0.013	2/21	PZ-303-AS
Dibenzo(a,h)anthracene	<0.0002 to <0.0002	<0.0002 to 0.002	3/19	PZ-107-D (MW-107)
Ethylbenzene	<0.002 to <0.002	<0.002 to 0.12	3/21	PZ-303-AS
Indeno(1,2,3-cd)pyrene	<0.00005 to <0.00005	<0.00005 to 0.00015	1/19	PZ-107-D (MW-107)
m+p Cresols	<0.01 to <0.01	<0.01 to 0.016	1/19	PZ-303-AS
Methyl ethyl ketone	<0.005 to <0.005	<0.005 to 0.007	1/21	PZ-303-AS
Naphthalene	<0.01 to <0.01	<0.01 to 0.032	2/19	PZ-303-AS
o-Cresol	<0.01 to <0.01	<0.01 to 0.022	2/19	PZ-303-AS
Styrene	<0.002 to <0.002	<0.002 to 0.006	0/21	PZ-303-AS
Toluene	<0.002 to <0.002	<0.002 to 0.4	3/21	PZ-303-AS
trans-1,3-Dichloropropylene	<0.002 to <0.002	<0.002 to 0.008	1/21	PZ-303-AS
Vinyl chloride	<0.001 to <0.001	<0.001 to 0.026	8/21	PZ-303-AS
Volatile Petroleum Hydrocarbons	<0.00005 to <0.00005	<0.00005 to 0.53	7/21	PZ-304-AI
Xylenes (Total)	<0.002 to <0.002	<0.002 to 0.67	4/21	PZ-303-AS

Note:
NR = Not Reported

Table 6-3. Summary of Detected Parameters from St. Louis/Upper Salem Groundwater Sampling

Parameter	Range of background concentrations	Range of detection results	Frequency of Detection	Piezometer exhibiting maximum detection concentration
Metals				
Antimony (Dissolved)	<0.003 to 0.008	<0.003 to 0.004	4/24	PZ-1201-SS
Antimony (Total)	<0.002 to 0.009	<0.003 to 0.007	4/24	PZ-102R-SS
Arsenic (Dissolved)	<0.002 to 0.008	<0.002 to 0.007	8/24	PZ-113-SS
Arsenic (Total)	0.002 to 0.007	<0.002 to 0.006	13/24	PZ-113-SS
Barium (Dissolved)	0.022 to 0.079	0.033 to 0.251	24/24	PZ-110-SS
Barium (Total)	0.037 to 0.1	0.054 to 0.252	24/24	PZ-110-SS
Boron (Dissolved)	<0.1 to 0.636	<0.1 to 0.282	5/24	PZ-110-SS
Boron (Total)	<0.1 to 0.80	<0.1 to 0.30	9/24	PZ-110-SS
Calcium (Dissolved)	40.1 to 66.9	49.6 to 219	24/24	PZ-110-SS
Calcium (Total)	41.0 to 75.4	60 to 214	25/25	PZ-110-SS
Chromium (Dissolved)	<0.01 to <0.01	<0.01 to 0.016	2/24	PZ-113-SS
Iron (Dissolved)	<0.04 to 0.665	<0.04 to 4.24	10/24	PZ-110-SS
Iron (Total)	<0.04 to 1.02	<0.04 to 5.87	23/24	PZ-110-SS
Magnesium (Dissolved)	25.1 to 37.6	26.3 to 80.0	24/24	PZ-110-SS
Magnesium (Total)	25.4 to 56.4	29.1 to 81	25/25	PZ-110-SS
Manganese (Dissolved)	0.045 to 0.063	<0.01 to 0.375	18/24	PZ-201A-SS
Manganese (Total)	0.045 to 0.064	0.017 to 0.528	24/24	PZ-201A-SS
Nickel (Dissolved)	<0.040 to <0.040	<0.04 to 0.048	1/24	PZ-110-SS
Nickel (Total)	<0.040 to <0.040	<0.04 to 0.055	2/24	PZ-110-SS
Selenium (Dissolved)	<0.002 to <0.002	<0.002 to 0.003	1/24	PZ-102R-SS
Selenium (Total)	<0.002 to <0.002	<0.002 to 0.003	2/24	PZ-102R-SS
Sodium (Dissolved)	30.1 to 153	11 to 114	24/24	PZ-110-SS
Sodium (Total)	28.1 to 154	11 to 115	25/25	PZ-110-SS
Zinc (Dissolved)	<0.030 to <0.030	<0.030 to 0.044	3/24	PZ-110-SS
Zinc (Total)	<0.030 to 0.133	<0.030 to 0.227	19/24	PZ-110-SS
Conventionals				
Ammonia as N	<0.1 to 0.2	<0.1 to 0.8	11/24	PZ-100-SS
Chemical Oxygen Demand	<15 to 50	<15 to 81	15/25	PZ-110-SS
Chloride	4 to 7	<3 to 215	23/24	PZ-110-SS
Fluoride	0.43 to 1.8	0.49 to 2.7	24/24	PZ-113-SS
Hardness, Total	220 to 360	290 to 900	25/25	PZ-110-SS
Nitrate/Nitrite	<0.1 to 0.2	<0.1 to 0.2	7/25	PZ-1201-SS
Phosphorus, Total	0.04 to 1.5	0.06 to 1.6	23/24	PZ-1201-SS
Sulfate, as SO4	20 to 73	26 to 141	25/25	PZ-102R-SS
Sulfide as S	<1 to 1	<1 to 4.3	26/26	PZ-102R-SS
Total Dissolved Solids	432 to 640	364 to 1418	24/24	PZ-110-SS
Total Organic Carbon	<1 to 7	<1 to 23	16/24	PZ-110-SS

Table 6-3. Summary of Detected Parameters from St. Louis/Upper Salem Groundwater Sampling (continued)

Parameter	Range of background concentrations	Range of detection results	Frequency of Detection	Piezometer exhibiting maximum detection concentration
Radionuclides (pCi/l)				
Gross Alpha (Dissolved)	<3.32 to 17.19 ± 5.24	<2.97 to 17.4 ± 5	18/25	PZ-100-SS
Gross Alpha (Total)	3.51 ± 2.69 to 28.8 ± 7.21	<4.61 to 29.3 ± 11.9	19/25	PZ-1201-SS
Gross Beta (Dissolved)	<3.72 to 9.28 ± 3.86	<3.6 to 19 ± 2.28	22/25	PZ-1201-SS
Gross Beta (Total)	4.37 ± 2.25 to 20.5 ± 4.37	<4.49 to 35.2 ± 10.7	17/25	PZ-1201-SS
Radium-226 (Dissolved)	<0.43 to 1.42 ± 0.563	<0.412 to 2.53 ± 0.733	22/25	PZ-106-SS
Radium-226 (Total)	0.78 ± 0.09 to 3.33 ± 0.769	<0.426 to 6.33 ± 1.26	25/25	PZ-106-SS
Uranium-234 (Dissolved)	0.89 ± 0.28 to 8.2 ± 1.37	<0.343 to 12.7 ± 1.46	24/25	PZ-100-SS
Uranium-234 (Total)	0.80 ± 0.26 to 9.78 ± 1.81	0.202 ± 0.146 to 20 ± 1.39	23/25	PZ-104-SS
Uranium-235/236 (Dissolved)	<0.141 to 0.769 ± 0.449	<0.151 to 1.25 ± 0.851	5/25	PZ-201A-SS
Uranium-235/236 (Total)	<0.169 to 0.516 ± 0.35	<0.123 to 0.746 ± 0.418	6/25	PZ-100-SS
Uranium-238 (Dissolved)	0.50 ± 0.20 to 3.36 ± 0.888	<0.151 to 6.27 ± 1.2	24/25	PZ-100-SS
Uranium-238 (Total)	0.25 ± 0.13 to 4.55 ± 1.25	0.134 to 6.39 ± 1.15	21/25	PZ-100-SS
Thorium-230 (Dissolved)	<0.502 to 0.29 ± 0.17	<0.442 to 0.934 ± 0.392	8/25	PZ-206-SS
Thorium-230 (Total)	<0.736 to 0.84 ± 0.29	<0.535 to 2.41 ± 1.1	13/25	PZ-1201-SS
Volatiles/Organics				
1,2-cis-Dichloroethylene	<0.002 to <0.002	<0.002 to 0.0024	1/24	GW-110-SS
Acetone	<0.005 to <0.005	<0.005 to 0.005	1/24	GW-1201-SS
Benzene	<0.002 to <0.002	<0.002 to 0.011	3/24	GW-1201-SS
gamma-Chlordane	<0.00005 to <0.00005	<0.00005 to 0.000051	1/24	GW-100-SS
Xylenes (Total)	<0.002 to <0.002	<0.002 to 0.67	4/24	GW-301-SS

Table 6-4. Summary of Detected Parameters from Deep Salem Groundwater Sampling

Parameter	Range of background concentrations	Range of detection results	Frequency of Detection	Piezometer exhibiting maximum detection concentration
Metals				
Arsenic (Dissolved)	<0.002 to 0.008	<0.002 to 0.002	2/11	PZ-100-SD
Arsenic (Total)	0.002 to 0.007	<0.002 to 0.002	3/11	PZ-100SD; PZ-106-SD
Barium (Dissolved)	0.022 to 0.079	0.045 to 0.273	11/11	PZ-100-SD
Barium (Total)	0.037 to 0.1	0.05 to 0.291	11/11	PZ-100-SD
Calcium (Dissolved)	40.1 to 66.9	75.8 to 119	11/11	PZ-104-SD
Calcium (Total)	41.0 to 75.4	81.2 to 116	11/11	PZ-104-SD
Iron (Dissolved)	<0.04 to 0.665	<0.04 to 0.945	7/11	MW-1204
Iron (Total)	<0.04 to 1.02	0.119 to 2.09	11/11	PZ-100-SD
Magnesium (Dissolved)	25.1 to 37.6	34.0 to 53.9	11/11	PZ-111-SD
Magnesium (Total)	25.4 to 56.4	34.3 to 53.4	11/11	PZ-111-SD
Manganese (Dissolved)	0.045 to 0.063	0.016 to 0.238	11/11	PZ-106-SD
Manganese (Total)	0.045 to 0.064	0.017 to 0.332	11/11	PZ-100-SD
Sodium (Dissolved)	30.1 to 153	11 to 59.9	11/11	PZ-106-SD
Sodium (Total)	28.1 to 154	11 to 59.1	11/11	PZ-106-SD
Zinc (Dissolved)	<0.030 to <0.030	<0.030 to 0.053	2/11	PZ-111-SD
Zinc (Total)	<0.030 to 0.133	<0.030 to 0.103	9/11	PZ-111-SD
Conventionals (mg/l)				
Ammonia as N	<0.1 to 0.2	<0.1 to 0.5	7/11	PZ-100-SD, PZ-106-SD
Chemical Oxygen Demand	<15 to 50	<15 to 92	3/11	PZ-106-SD
Chloride	4 to 7	<3 to 56	10/11	PZ-104-SD
Fluoride	0.43 to 1.8	0.77 to 2.4	11/11	PZ-1204-SD
Hardness, Total	220 to 360	340 to 500	11/11	PZ-104-SD
Nitrate/Nitrite	<0.1 to 0.2	<0.1 to 0.3	3/11	PZ-106-SD
Phosphorus, Total	0.04 to 1.5	<0.01 to 0.37	9/11	PZ-106-SD
Sulfate, as SO4	20 to 73	10 to 120	11/11	PZ-106-SD
Sulfide as S	<1 to 1	<1 to 1	4/11	PZ-106-SD; PZ-111-SD; MW-1204
Total Dissolved Solids	432 to 640	340 to 665	11/11	PZ-106-SD
Total Organic Carbon	<1 to 7	<1 to 26	5/11	PZ-106-SD
Radionuclides (pCi/l)				
Gross Alpha (Dissolved)	<3.32 to 17.19 ± 5.24	<3.13 to 10.8 ± 4.98	3/10	PZ-106-SD
Gross Alpha (Total)	3.51 ± 2.69 to 28.8 ± 7.21	<4.18 to 12.3 ± 5.4	5/10	PZ-106-SD
Gross Beta (Dissolved)	<3.72 to 9.28 ± 3.86	<4.14 to 6.73 ± 2.19	3/10	PZ-100-SD
Gross Beta (Total)	4.37 ± 2.25 to 20.5 ± 4.37	<3.56 to 9.53 ± 3.61	4/10	MW-1204
Radium-226 (Dissolved)	<0.43 to 1.42 ± 0.563	<0.706 to 2.38 ± 0.729	9/10	MW-1204
Radium-226 (Total)	0.78 ± 0.09 to 3.33 ± 0.769	<0.678 to 2.98 ± 0.898	9/10	PZ-100-SD
Uranium-234 (Dissolved)	0.89 ± 0.28 to 8.2 ± 1.37	<0.283 to 2.32 ± 0.541	9/10	PZ-106-SD
Uranium-234 (Total)	0.80 ± 0.26 to 9.78 ± 1.81	<0.628 to 15.3 ± 1.82	8/10	MW-1204
Uranium-235/236 (Dissolved)	<0.141 to 0.769 ± 0.449	<0.13 to 0.315 ± 0.176	1/10	PZ-100-SD
Uranium-235/236 (Total)	<0.169 to 0.516 ± 0.35	<0.159 to 0.744 ± 0.416	1/10	MW-1204
Uranium-238 (Dissolved)	0.50 ± 0.20 to 3.36 ± 0.888	<0.283 to 2.57 ± 1.14	7/10	PZ-106-SD
Uranium-238 (Total)	0.25 ± 0.13 to 4.55 ± 1.25	<0.346 to 6.9 ± 1.2	9/10	MW-1204
Thorium-230 (Dissolved)	<0.502 to 0.29 ± 0.17	<0.283 to 1.05 ± 0.326	4/10	PZ-100-SD
Thorium-230 (Total)	<0.736 to 0.84 ± 0.29	<0.473 to 0.845 ± 0.288	3/10	PZ-100-SD
Volatiles/ Organics				
Benzene	<0.002 to <0.002	<0.002 to 0.013	1/11	GW-111-SD
Volatile Petroleum Hydrocarbons	<0.00005 to <0.00005	<0.00005 to 0.53	1/11	GW-111-SD
Xylenes (Total)	<0.002 to <0.002	<0.002 to 0.67	1/11	GW-1204-SD-D

Table 6-5. Comparison between Compounds Detected in Leachate and Compounds of Concern (COCs) in Groundwater

Compound	Range of Detection Results	Piezometer Exhibiting the Maximum Detection Concentration	COC in Groundwater (Y/N)
Metals			
Arsenic	***0.009 to 0.176***	***LC-LR-103***	***Y***
Volatiles/Organics			
Acetone	<0.010 to 1.2	LC-LCS-1	N
Benzene	***<0.005 to 0.009***	***LC-LCS-2***	***Y***
Chlorobenzene	<0.005 to 0.74	LC-LR-105	N
1,4-Dichlorobenzene	<0.005 to 0.081	LC-LCS-2	N
Ethylbenzene	<0.005 to 0.089	LC-LR-105	N
2-Hexanone	<0.010 to 0.18	LC-LCS-4	N
Methyl Ethyl Ketone	<0.010 to 3.0	LC-LCS-1	N
Methyl iso-butyl Ketone	<0.010 to 0.08	LC-LCS-2	N
Styrene	<0.005 to 0.006	LC-LCS-4	N
Toluene	<0.005 to 0.15	LC-LCS-3	N
Total Xylenes	<0.005 to 0.43	LC-LR-105	N
m+p Cresol	<0.010 to 1.9	LC-LCS-1	N
2,4-Dimethylphenol	<0.010 to 0.082	LC-LR-105	N
Diethyl phthalate	<0.010 to 0.033	LC-LCS-1	N
Dimethyl phthalate	<0.010 to 0.012	LC-LCS-1	N
Phenol	<0.010 to 0.29	LC-LCS-1	N
Naphthalene	<0.010 to 0.011	LC-LR-100	N
Volatile Petroleum Hydrocarbons	<0.05 to 0.95	LC-LR-105	N
Petroleum Hydrocarbons (Diesel)	0.08 to 79	LC-LCS-1	N

Table 6-6. Inactive Landfill Gas Concentrations, West Lake Landfill

Compound	Sampling Location										
	LG-01	LG-02	LG-03	LG-04	LG-05	LG-06	LG-07	LG-08	LG-09	LG-10	LG-1201-SS
1,2,4-Trimethylbenzene	ND	ND	***2.9***	***2.3***	***260***	***2.6***	ND	ND	ND	***44***	ND
1,2-cis-Dichloroethylene	ND	ND	ND	***7.1***	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorotetrafluoroethane	***410***	ND	***140***	***180***	ND	***0.88***	***140***	***520***	ND	***1.9***	ND
1,3,5-Trimethylbenzene	ND	ND	ND	ND	***68***	ND	ND	ND	ND	***24***	ND
1,4-Dichlorobenzene	ND	ND	ND	ND	***66***	ND	ND	ND	ND	***12***	ND
4-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	***46***	ND
Acetone	***150***	ND	***21***	***32***	***24000***	***40***	ND	***430***	ND	***84***	***18***
Benzene	***180***	ND	***110***	***92***	ND	***1.3***	ND	***410***	***190***	***81***	***2.2***
Carbon disulfide	***130***	ND	ND	***22***	ND	ND	ND	ND	ND	ND	***26***
Chlorobenzene	ND	ND	ND	ND	***1100***	ND	***280***	***150***	ND	***670***	ND
Chloroethane	***250***	ND	***120***	***87***	ND	ND	ND	110	ND	ND	ND
Dichlorodifluoromethane	***760***	***32***	***46***	***98***	ND	***1.6***	***230***	***600***	***78***	***2***	ND
Ethylbenzene	ND	ND	***7.2***	***5***	***210***	ND	ND	***52***	ND	***240***	***1.2***
m+p Xylenes	ND	ND	***4***	***6.6***	***360***	***2.3***	***100***	***130***	***22***	***640***	***5.4***
Methyl chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	***12***
Methyl ethyl ketone	ND	ND	ND	ND	ND	ND	ND	180	ND	***81***	***34***
Methylene chloride	***13***	ND	***4.1***	***5.8***	ND	ND	***61***	***22***	***17***	***1.7***	***1.6***
o-Xylene	ND	ND	ND	ND	***200***	***1.4***	ND	***49***	ND	***270***	***2***
Toluene	***1200***	ND	***5.8***	***13***	ND	***2.3***	ND	***200***	***34***	***210***	***4.2***
Trichlorofluoromethane	14	ND	ND	ND	ND	ND	ND	ND	ND	20	ND
Vinyl Chloride	***120***	ND	***61***	***76***	ND	***0.9***	ND	***740***	***100***	ND	ND

Notes:
Results are in ppbv.
ND = Not detected.

Table 6-7. RfDs for all Contaminants of Concern at OU-2 and Associated Uncertainty Factors, Primary Target Organs, and Modifying Factors

Contaminants of Concern (COCs)	Reference Dose ** (RfD)	(units)	Uncertainty Factor (UF)	Critical Effect	Modifying Factor	Confidence Level ***
Oral	**RfDo**					
Arsenic	3.00E-04	mg/kg-d	3*	Multiple: Lung, Skin, Liver, Kidney, Bladder*	1*	M*
Benzene	3.00E-03	mg/kg-d	NA	Hematopoetic System	NA	NA
Chloride	NA	NA	NA	NA	NA	NA
Fluoride	6.00E-02	mg/kg-d	1*	Dental Fluorosis*	1*	H*
Iron	3.00E-01	mg/kg-d	NA	NA	NA	NA
Manganese	1.40E-01	mg/kg-d	1*	Respiratory System, nervous system*	1*	M*
Vinyl Chloride	NA	NA	NA	NA	NA	NA
Total Petroleum Hydrocarbons	NA	NA	NA	NA	NA	NA

* Source: U.S. EPA Integrated Risk Information System, online at http://www.epa.gov/iris, February 3, 2000.

NA: Not Available

** Source: U.S.EPA Region 9 Preliminary Remediation Goals (PRGs), October 1, 1999.

*** Confidence Level: H=High, M=Medium, L=Low

Source: U.S. EPA Health Effects Assessment Summary Tables (HEAST), 1997.

Table 6-8. Toxicity Information for Carcinogenic COCs

Contaminants of Concern (COCs)	Slope Factor (SF)	(units)	Weight of Evidence Classification
Oral			
Arsenic	1.50E+00	1 mg/kg-d*	A; Human Carcinogen*
Benzene	2.90E-02	1 mg/kg-d*	A; Human Carcinogen*
Vinyl Chloride	1.90E+00	1 mg/kg-d**	A; Human Carcinogen*

* Source: U.S. EPA Integrated Risk Information System, on line at http://www.epa.gov/iris/, February 3, 2000.

** Source: U.S. EPA Health Effects Assessment Summary Tables (HEAST), 1997.

Figures

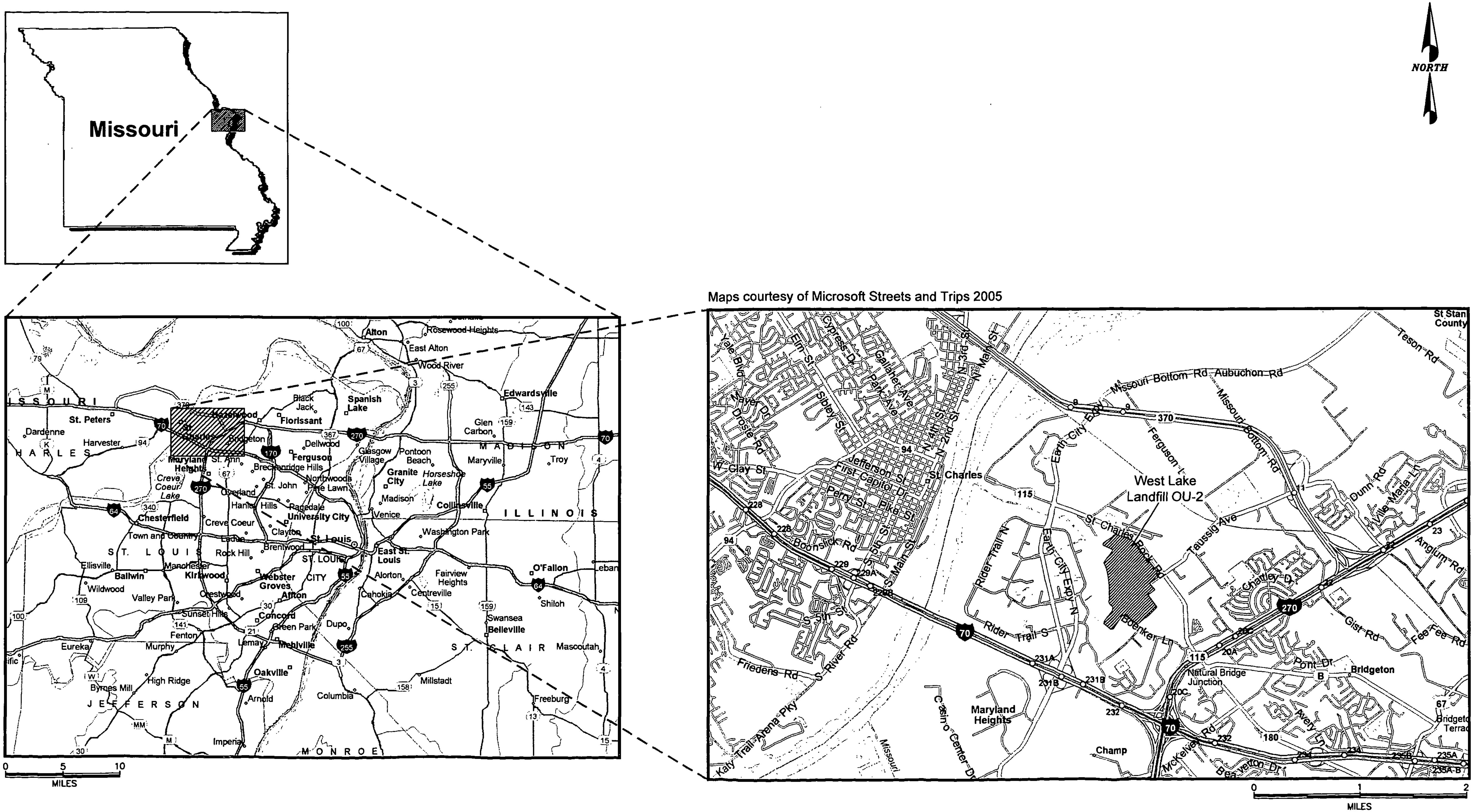

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Figure 1-1
Site Location Map

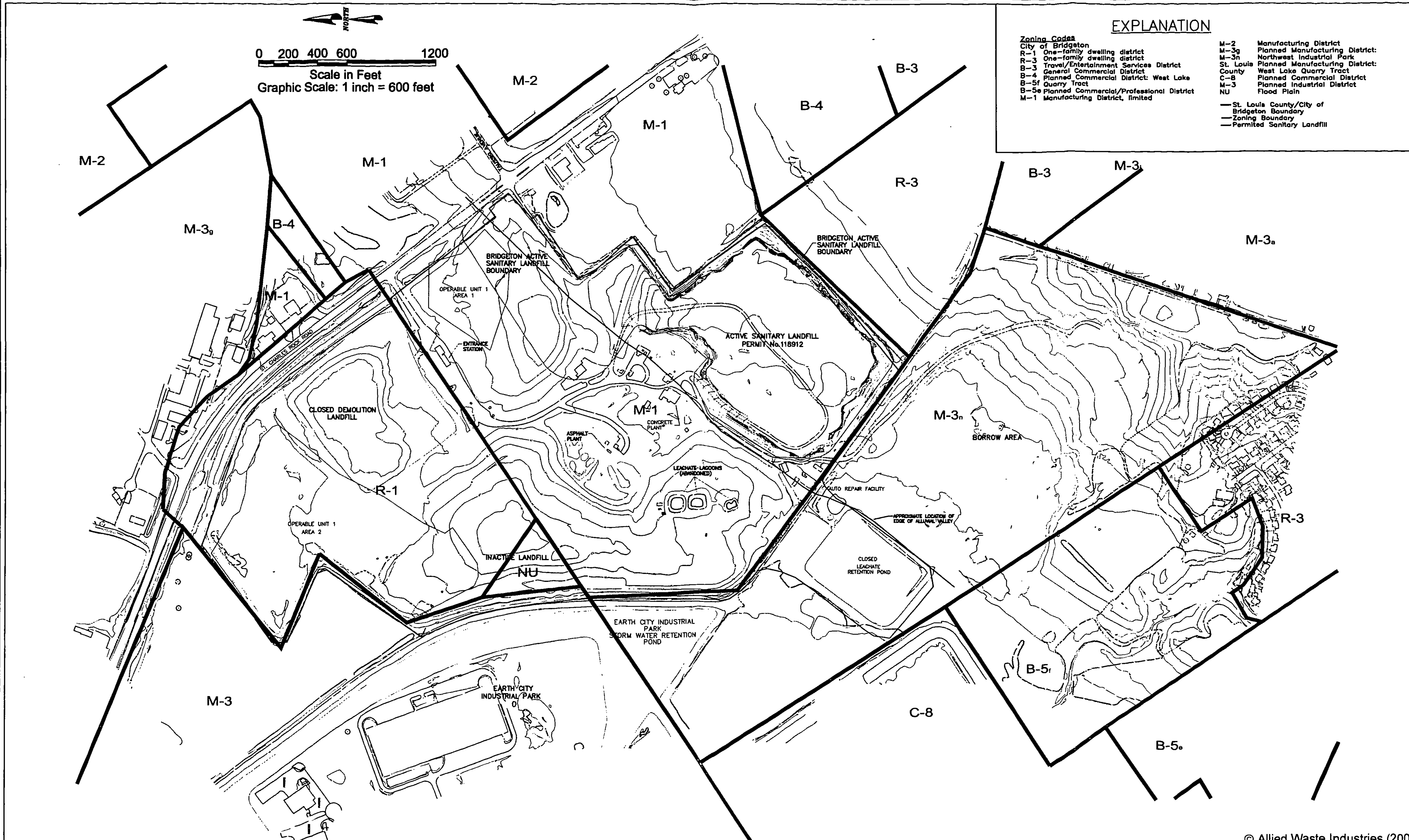

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Figure 1-2
Zoning and Land Use Map

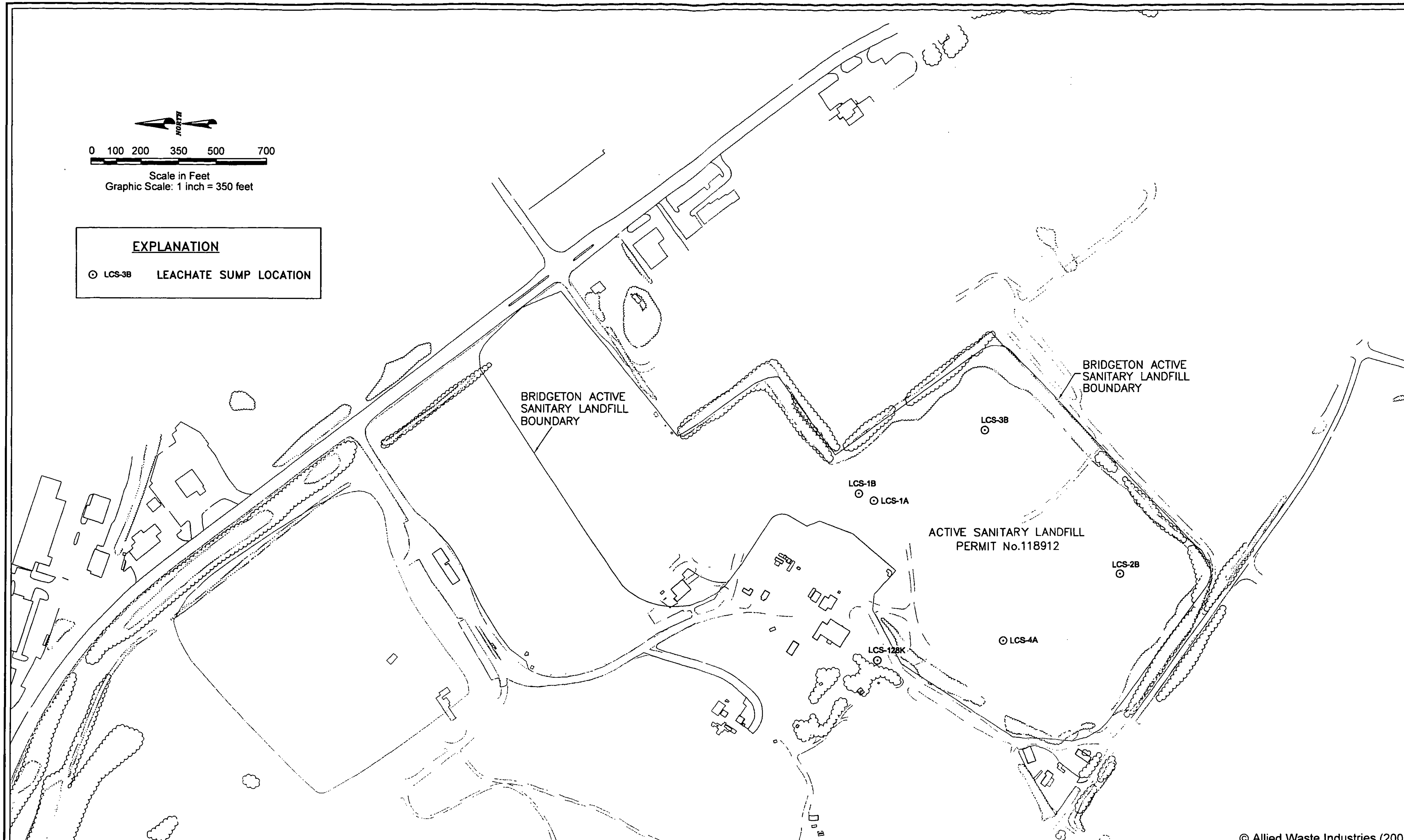

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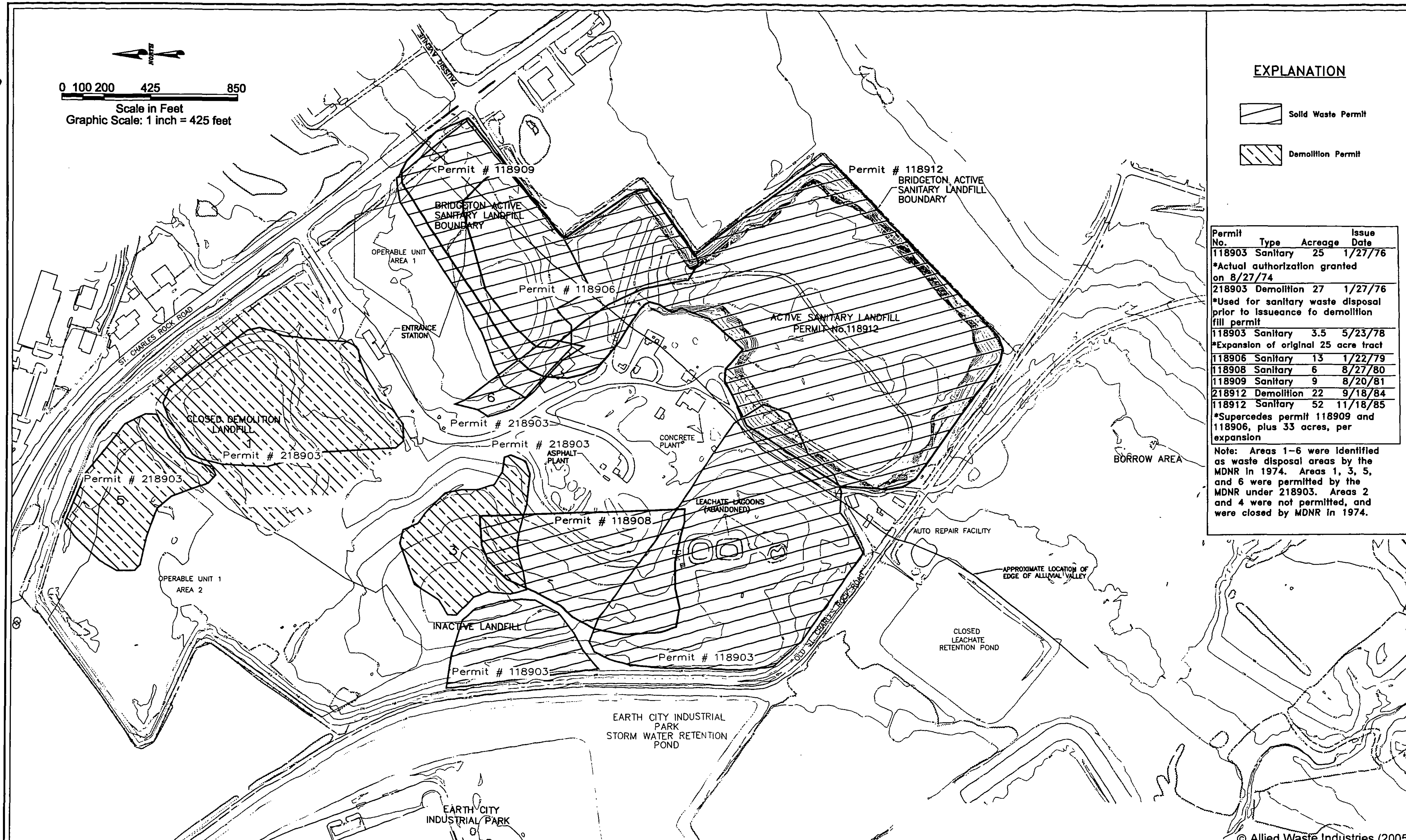
Figure 1-3
Leachate Riser Locations



Permit No.	Type	Acreage	Issue Date
118903	Sanitary	25	1/27/76
*Actual authorization granted on 8/27/74			
218903	Demolition	27	1/27/76
*Used for sanitary waste disposal prior to issueance fo demolition fill permit			
118903	Sanitary	3.5	5/23/78
*Expansion of original 25 acre tract			
118906	Sanitary	13	1/22/79
118908	Sanitary	6	8/27/80
118909	Sanitary	9	8/20/81
218912	Demolition	22	9/18/84
118912	Sanitary	52	11/18/85
*Supercedes permit 118909 and 118906, plus 33 acres, per expansion			

Note: Areas 1–6 were identified as waste disposal areas by the MDNR in 1974. Areas 1, 3, 5, and 6 were permitted by the MDNR under 218903. Areas 2 and 4 were not permitted, and were closed by MDNR in 1974.

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Figure 1-4
Missouri Department of Natural Resources
Permitted Areas

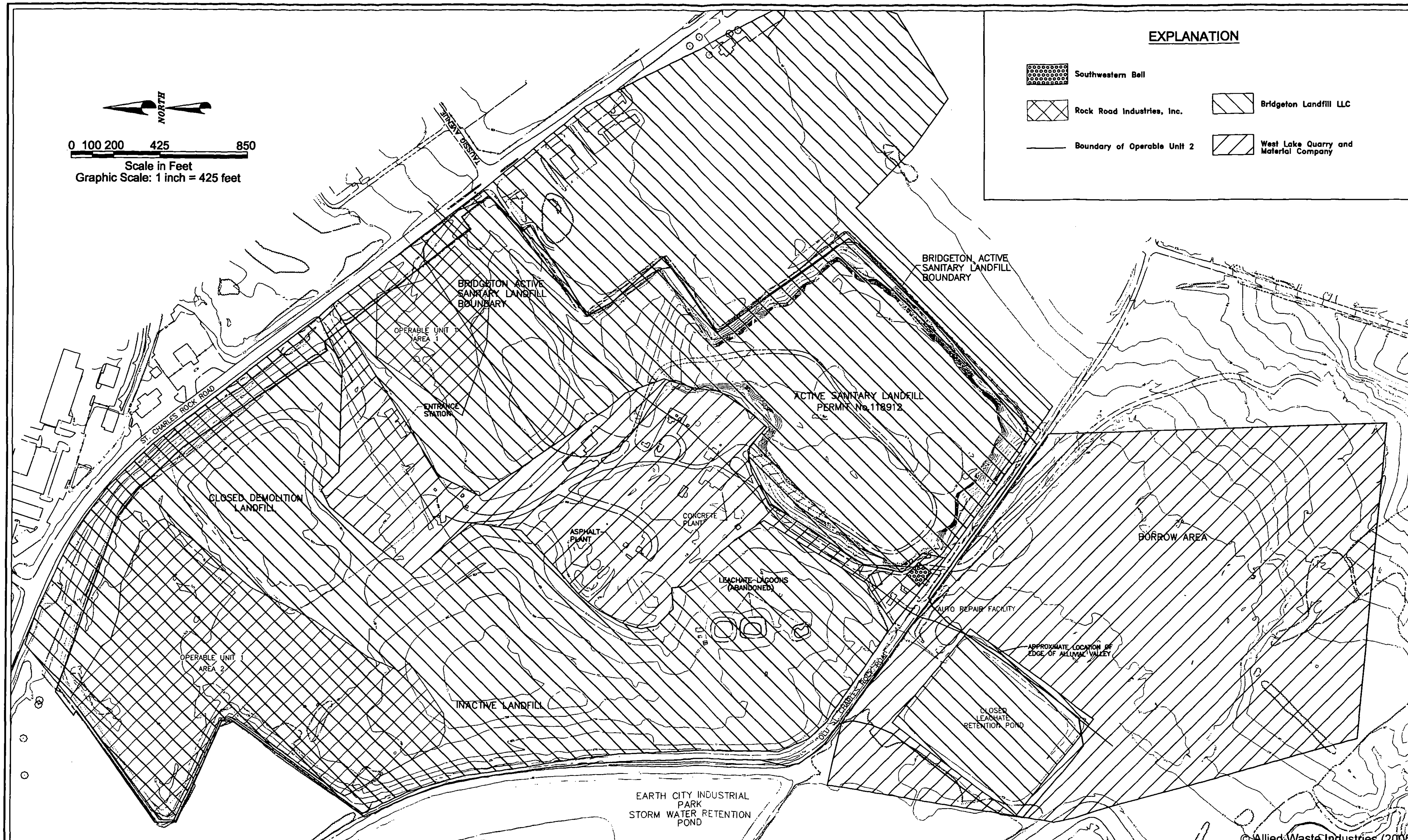

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Figure 1-5
Site Ownership Map

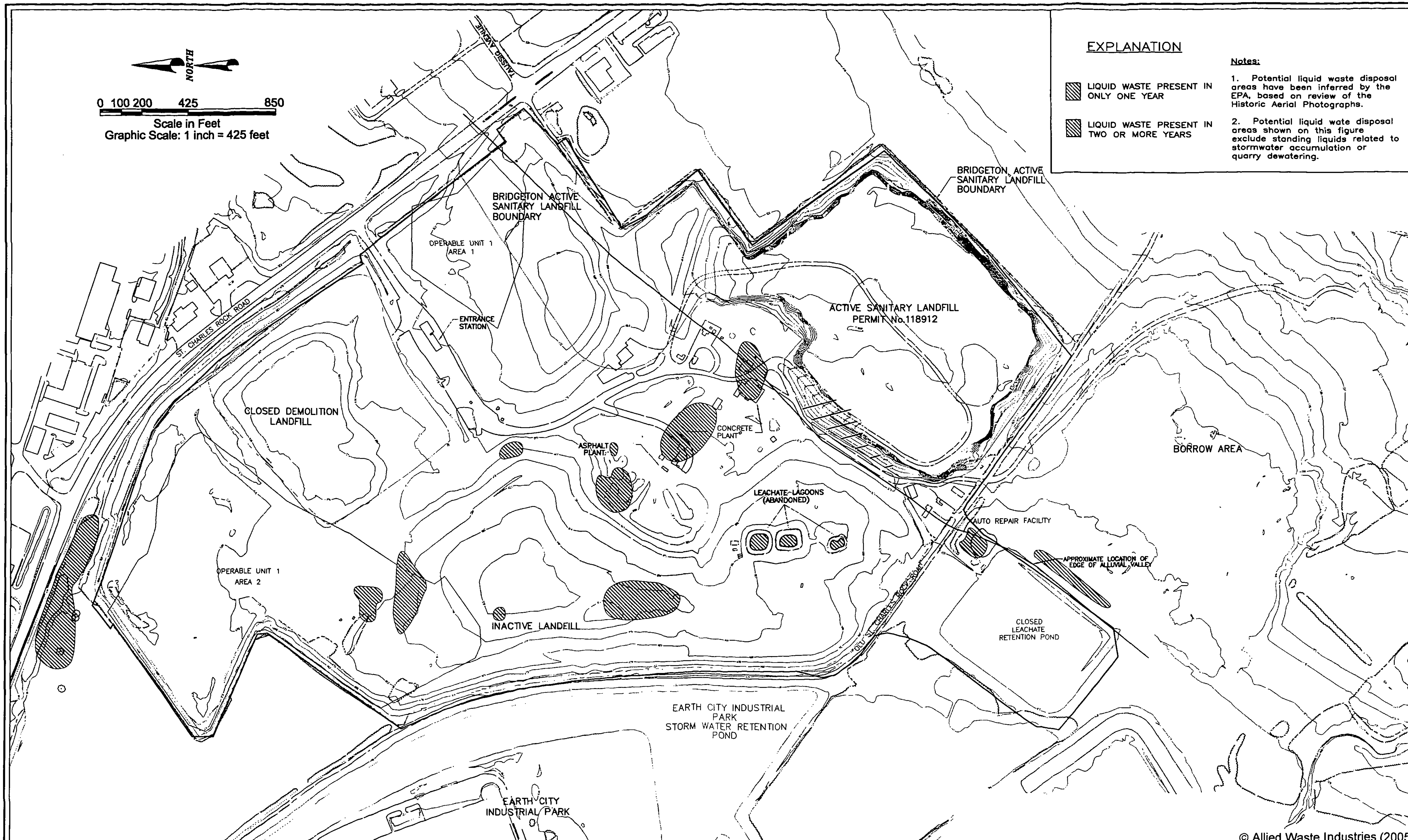

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Figure 1-6
Potential Liquid Disposal Areas Inferred by EPA

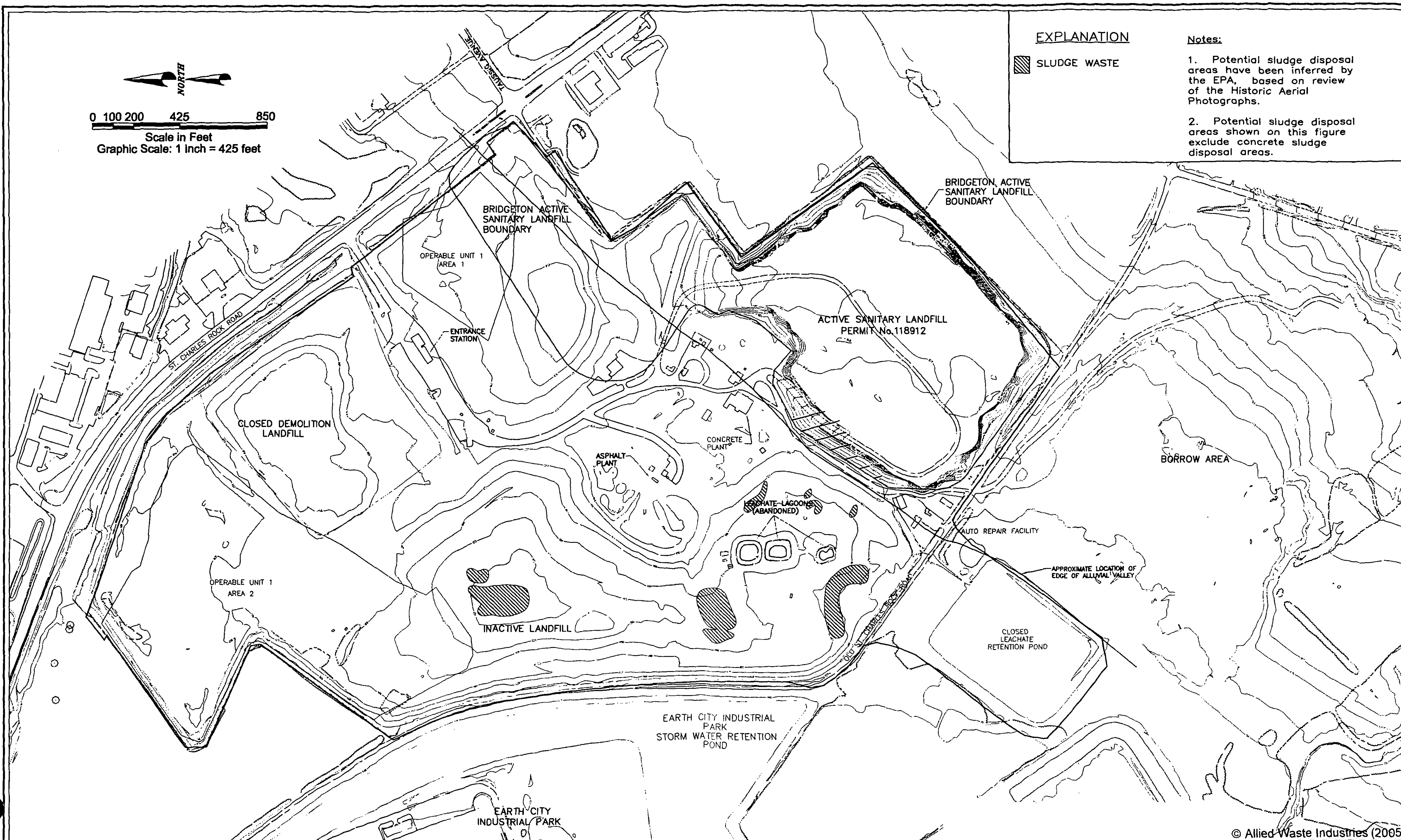

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Figure 1-7
Potential Sludge Disposal Areas

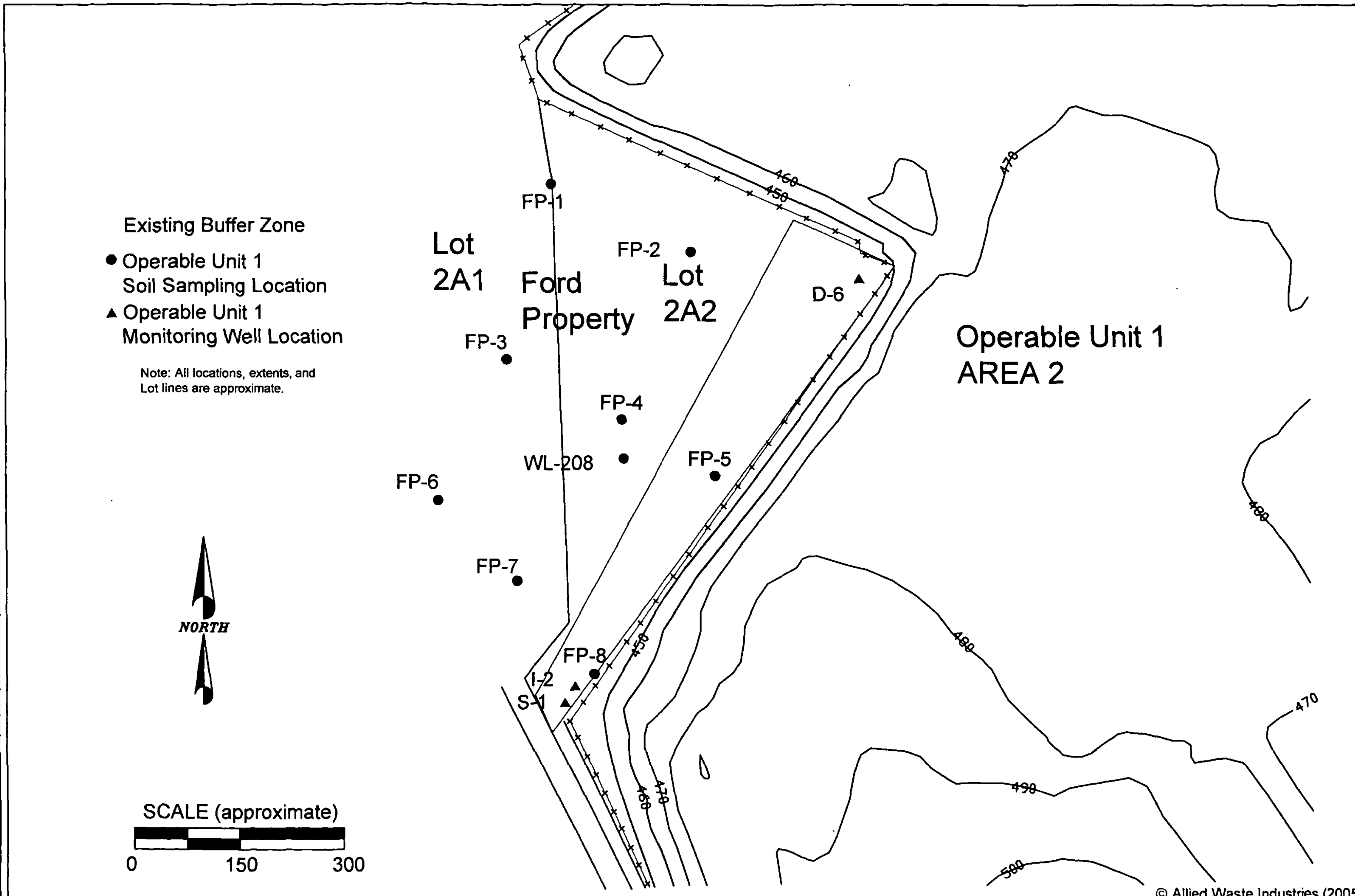

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Figure 1-8
Ford Property Map

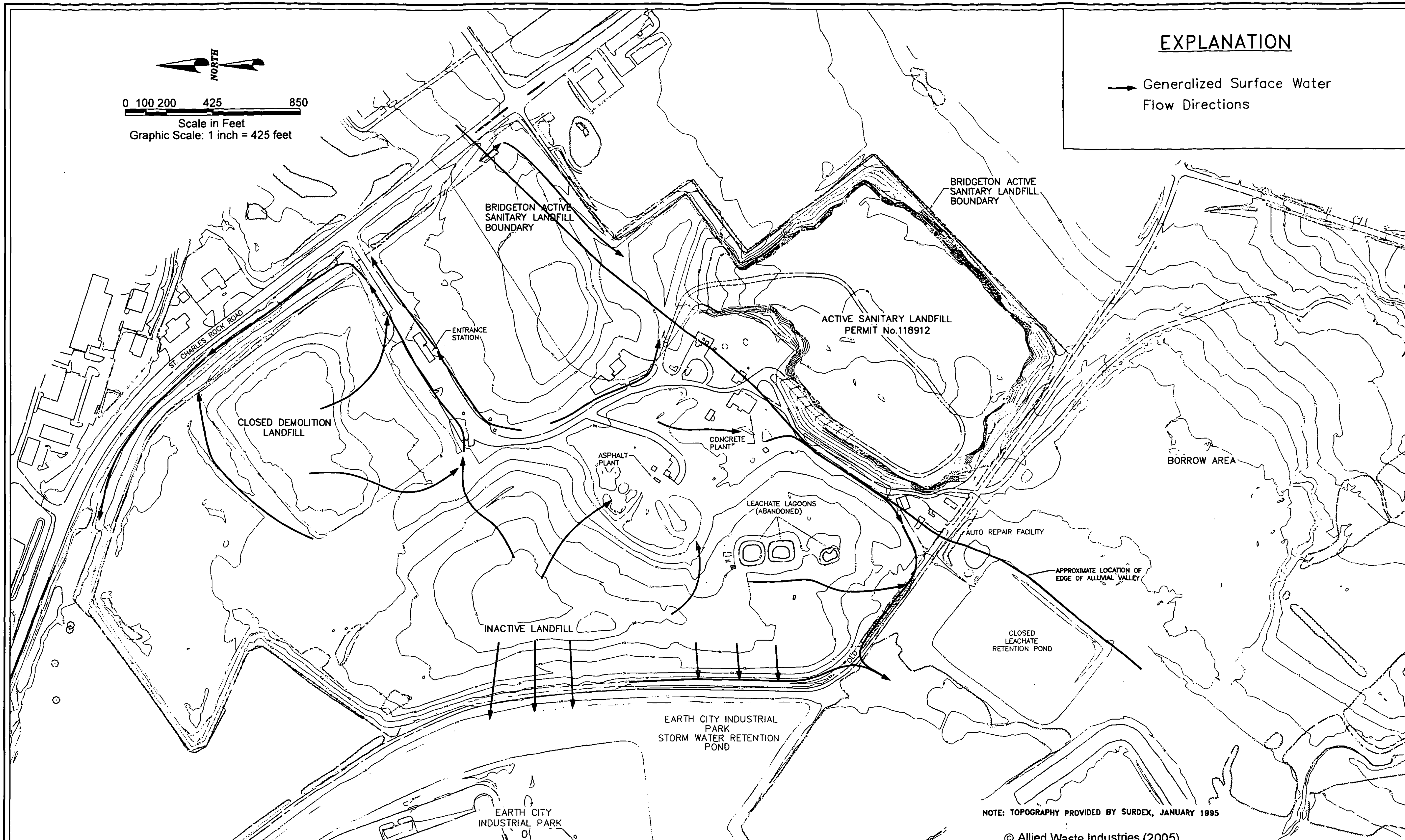

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Figure 2-1
Surface Water Drainage

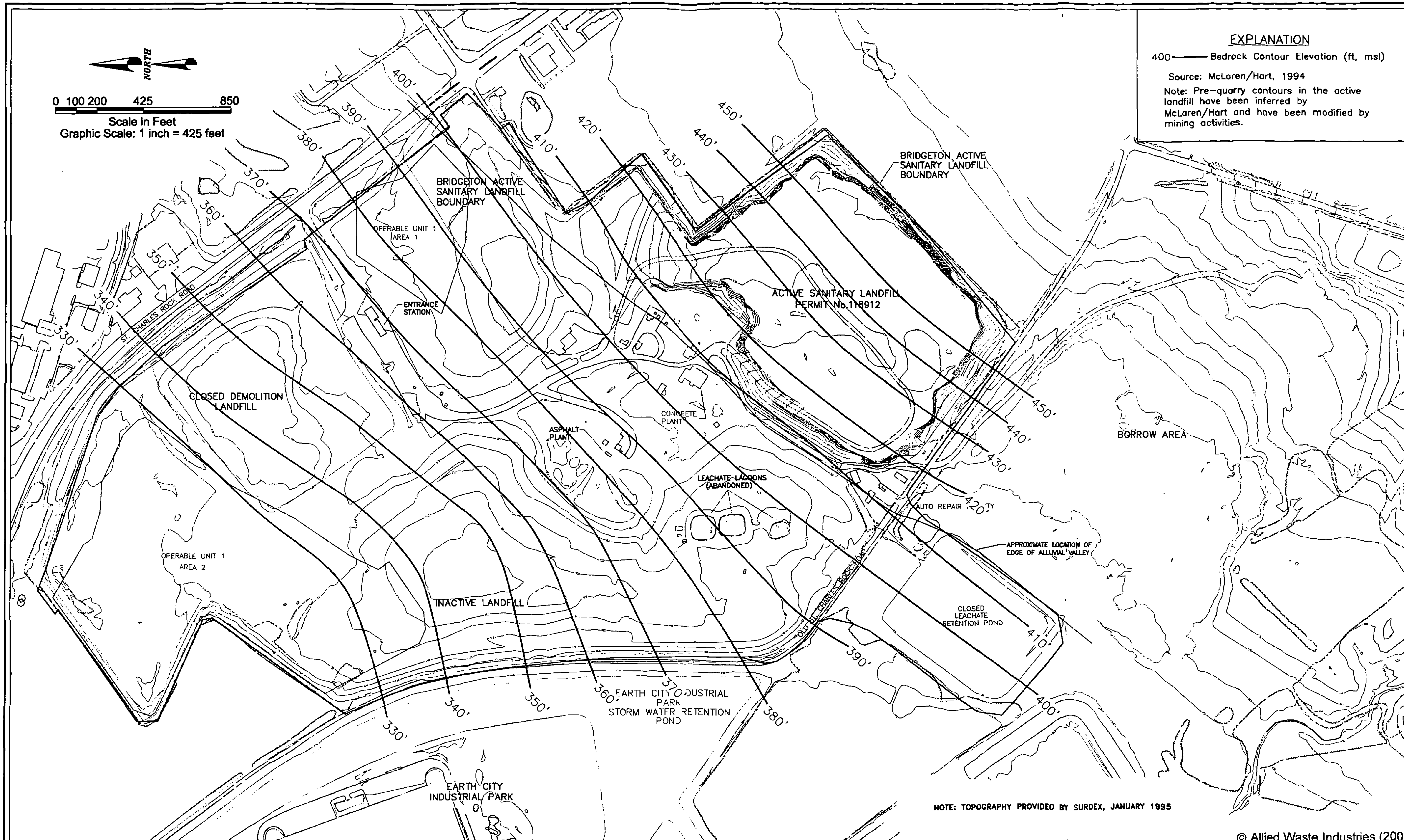

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Figure 2-2
Bedrock Contour Map

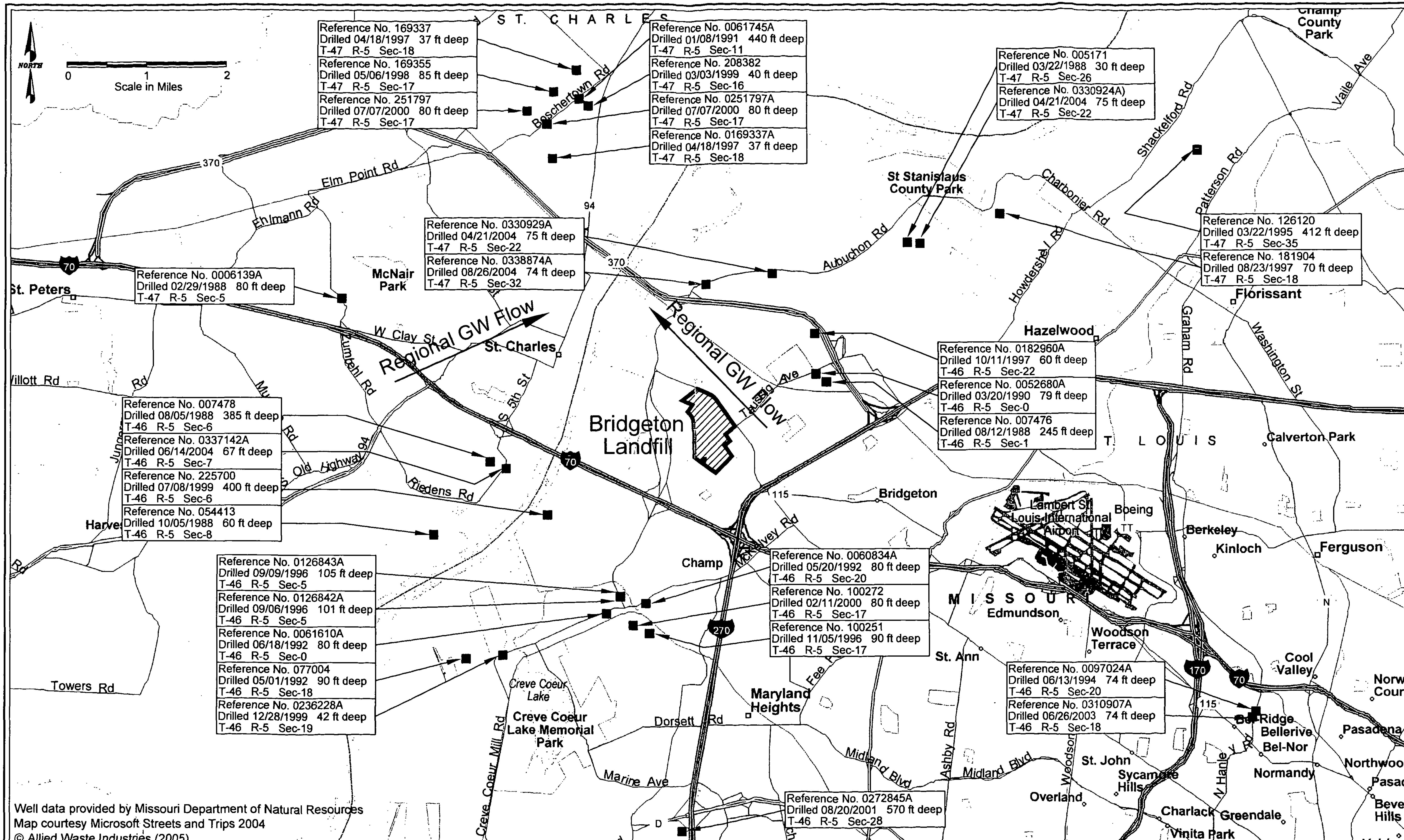

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Figure 2-3
Registered Wells Near West Lake Landfill

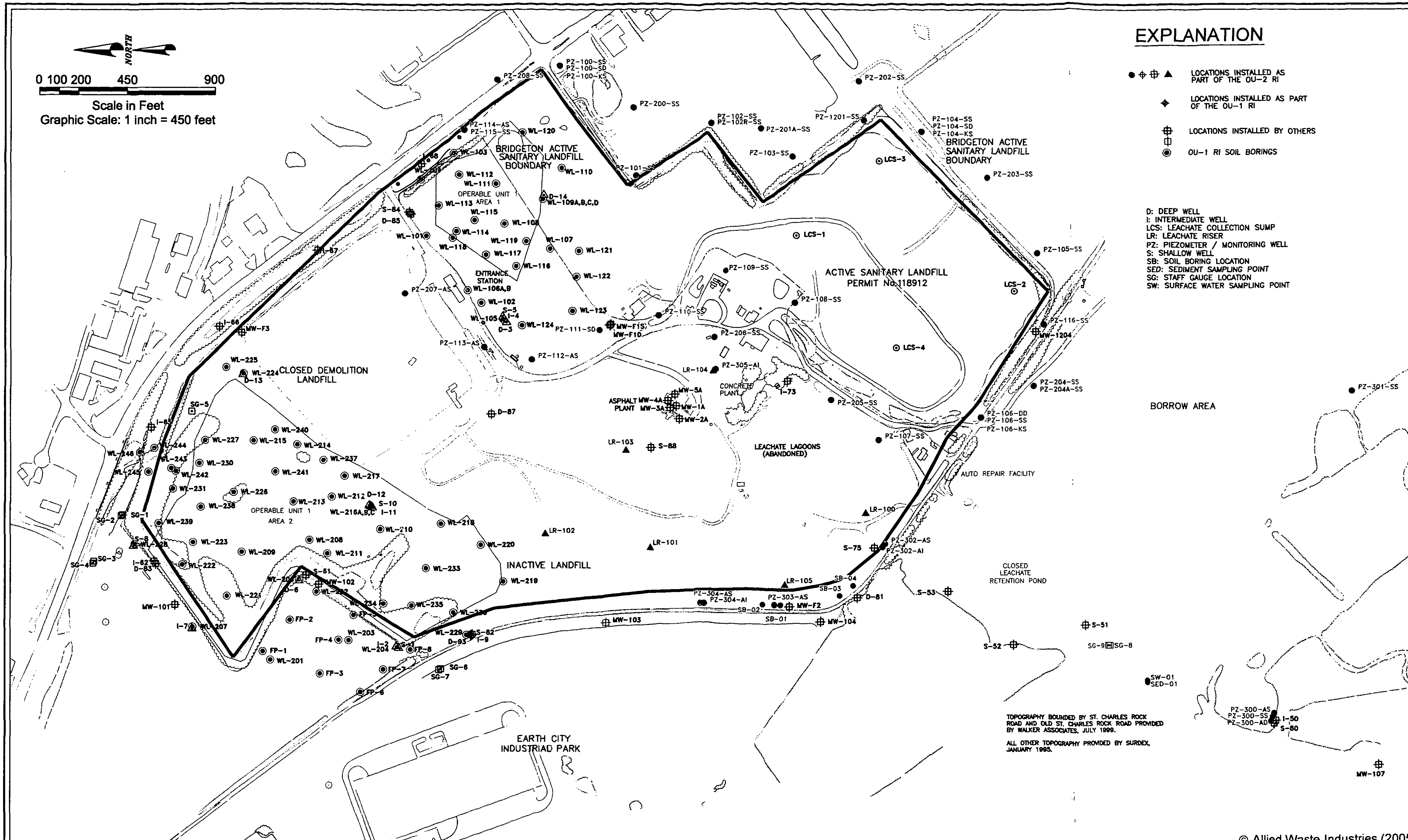

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Figure 3-1
Environmental Sampling Locations

Figure 3-2. Typical Piezometer Construction Details

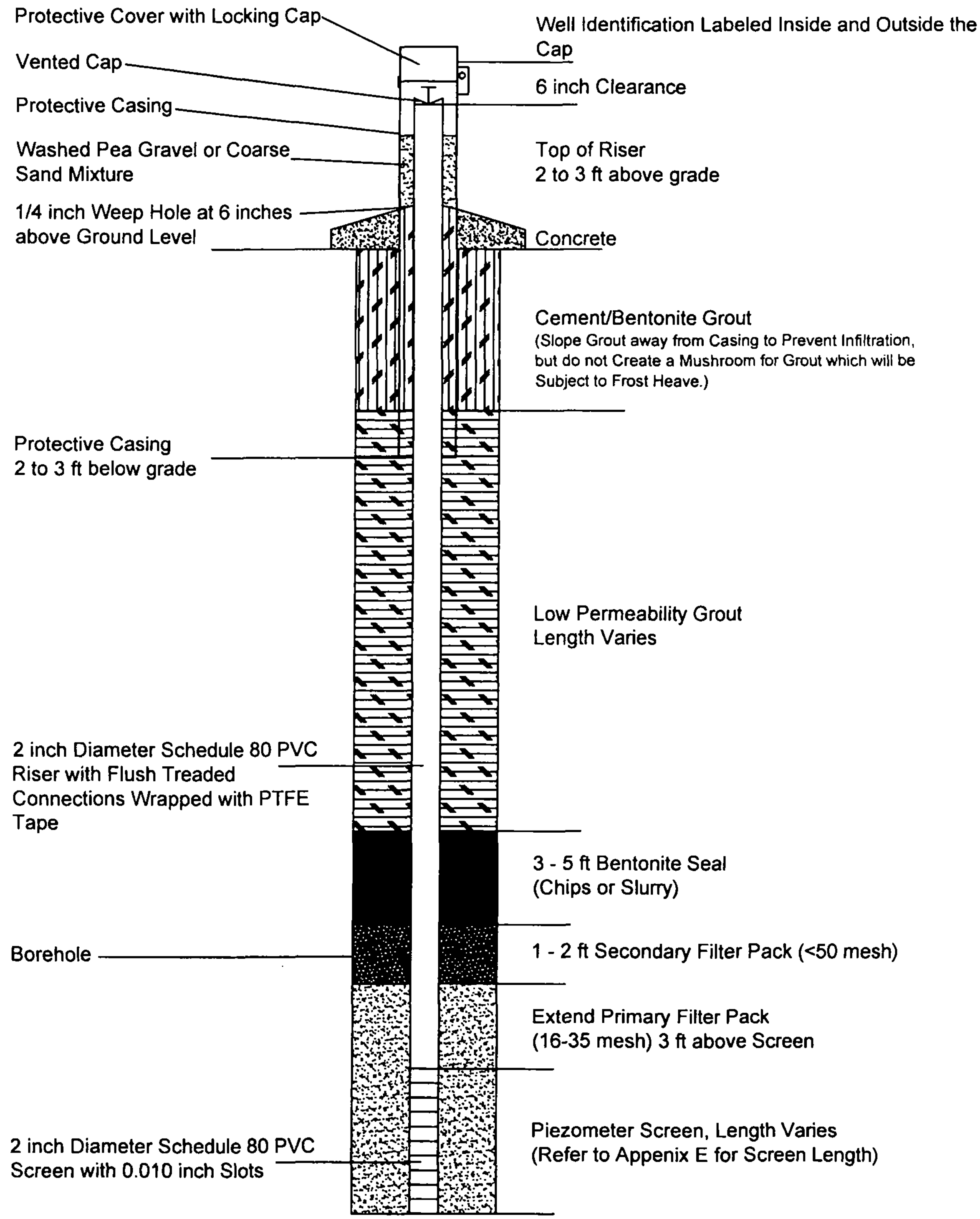

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Figure 3-2
Typical Piezometer Construction Details

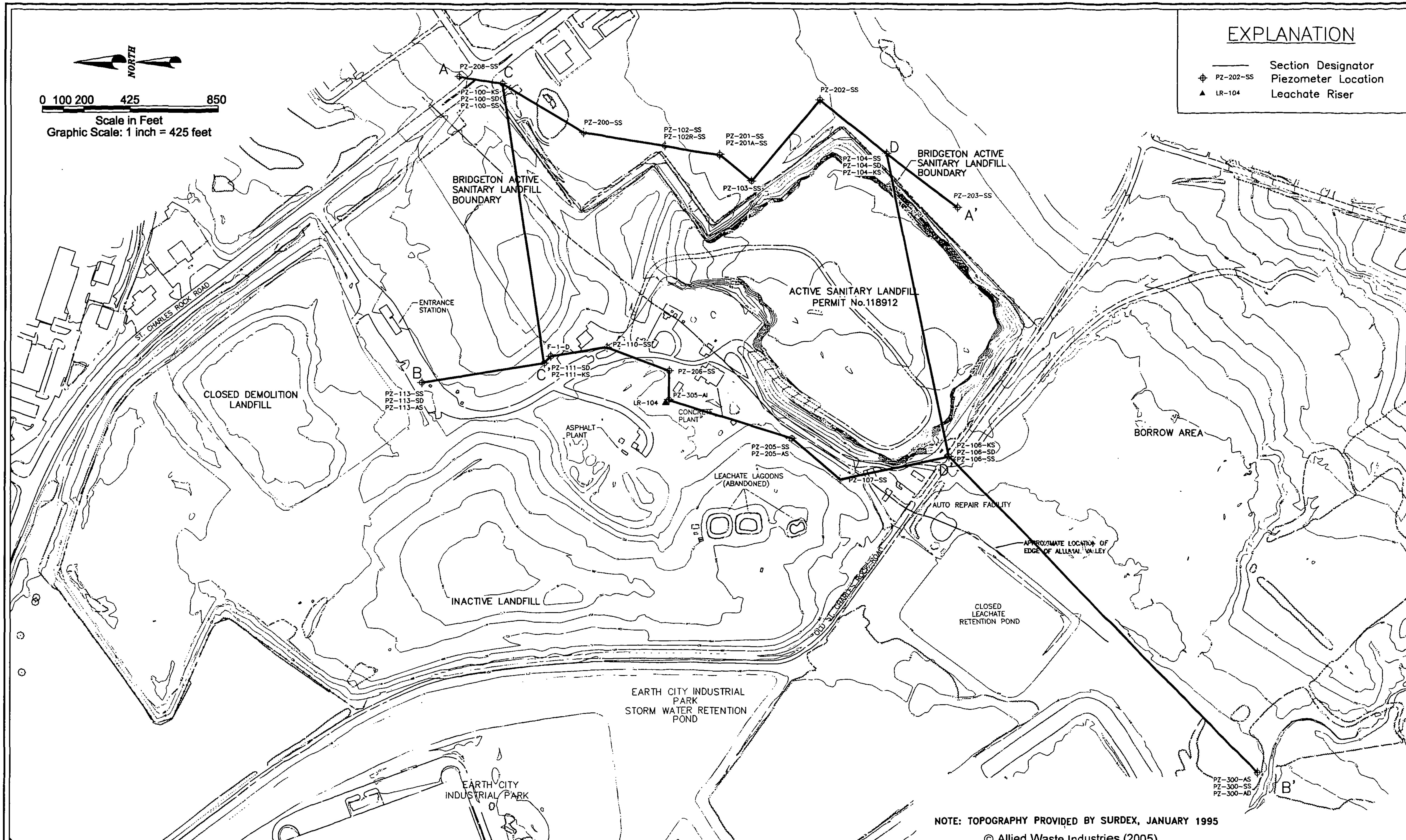

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Figure 3-3
Geologic Cross Section Location Map

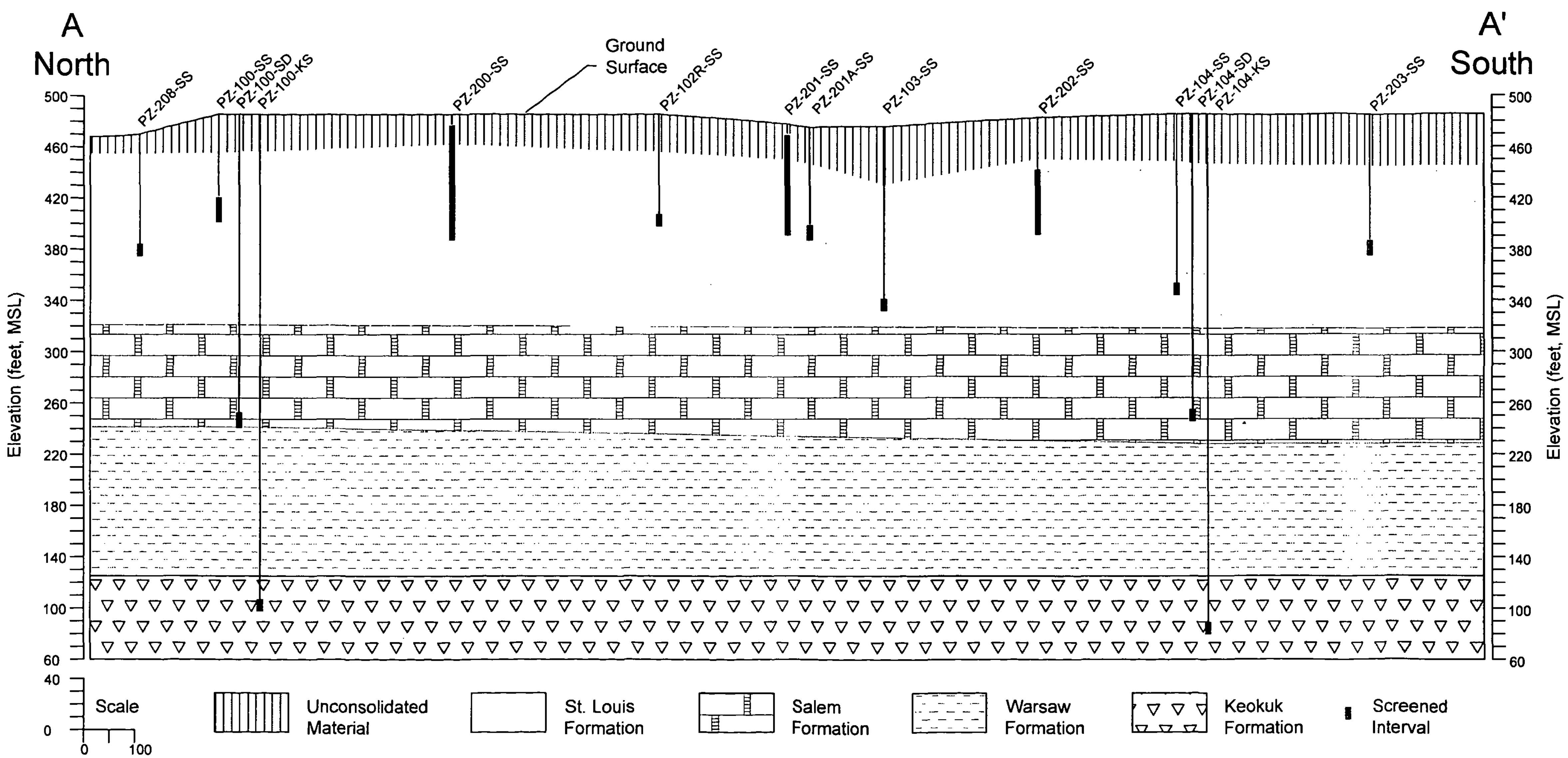

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Figure 3-4
Geologic Cross Section A-A'

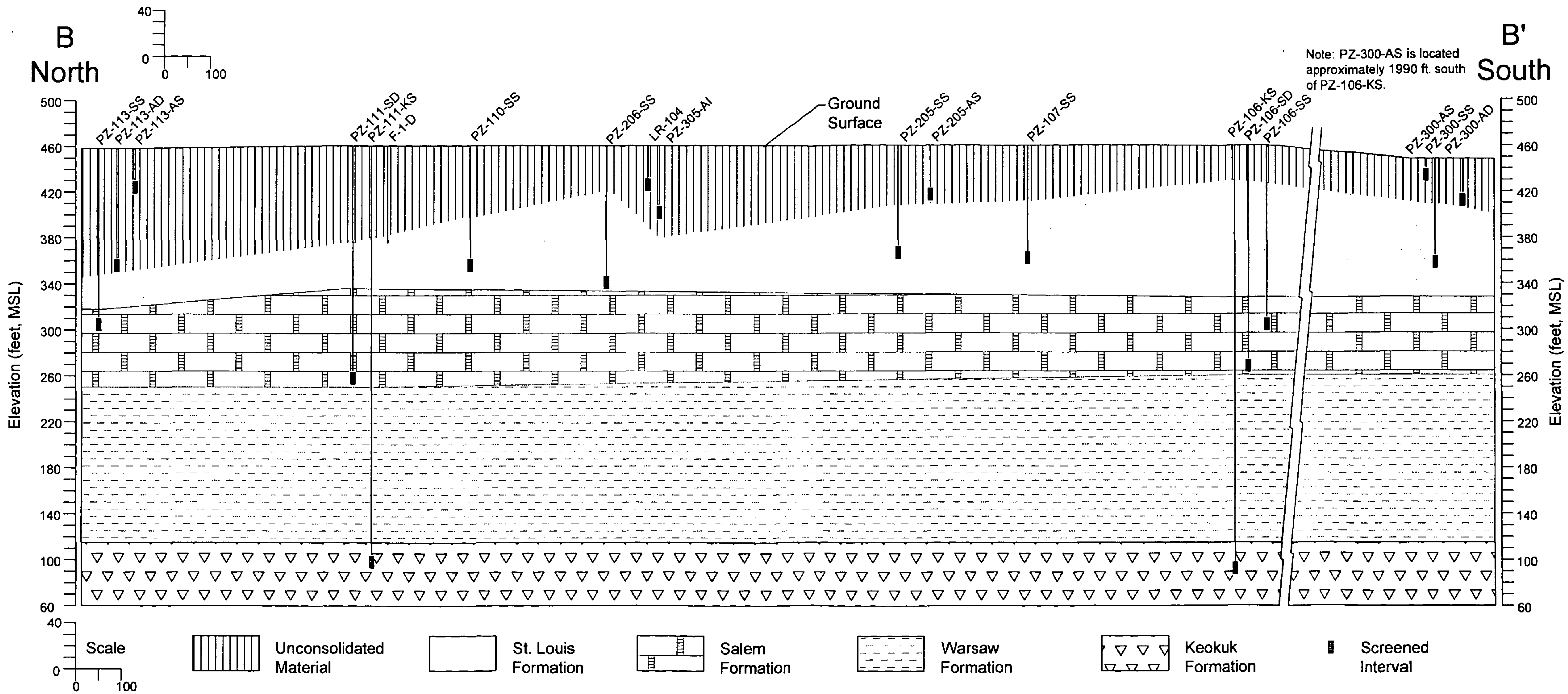

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Figure 3-5
Geologic Cross Section B-B'

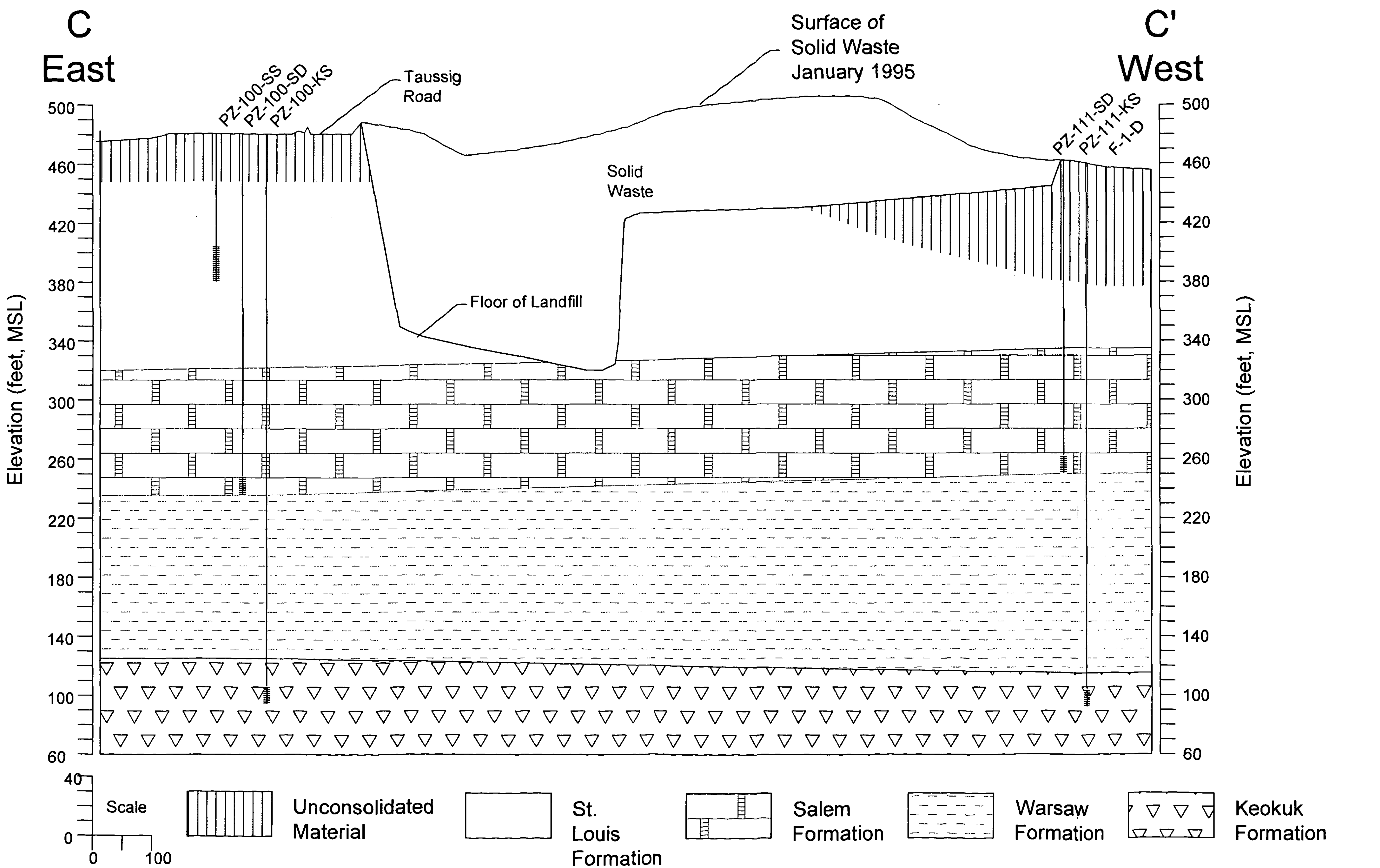

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Figure 3-6
Geologic Cross Section C-C'

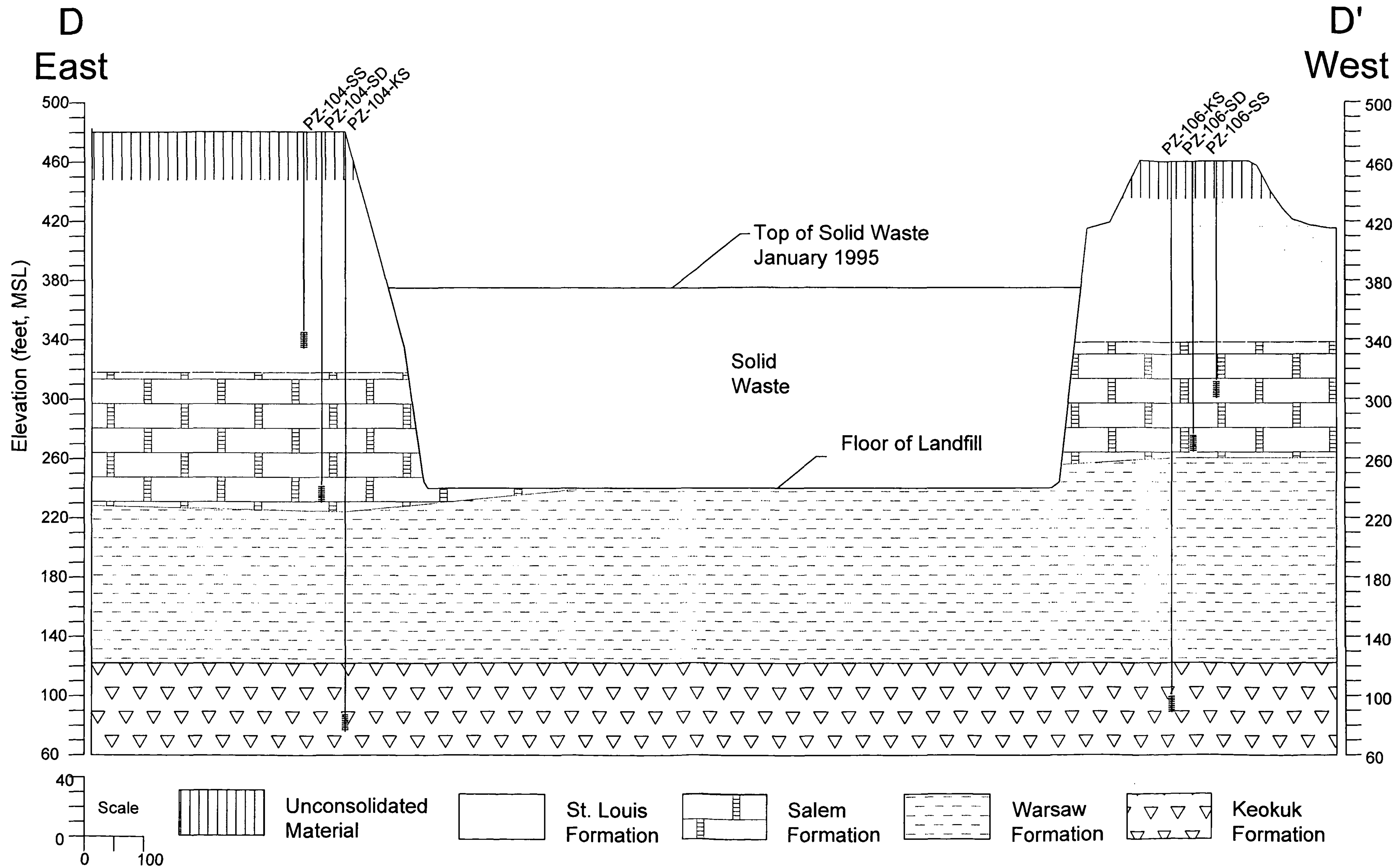

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Figure 3-7
Geologic Cross Section D-D'

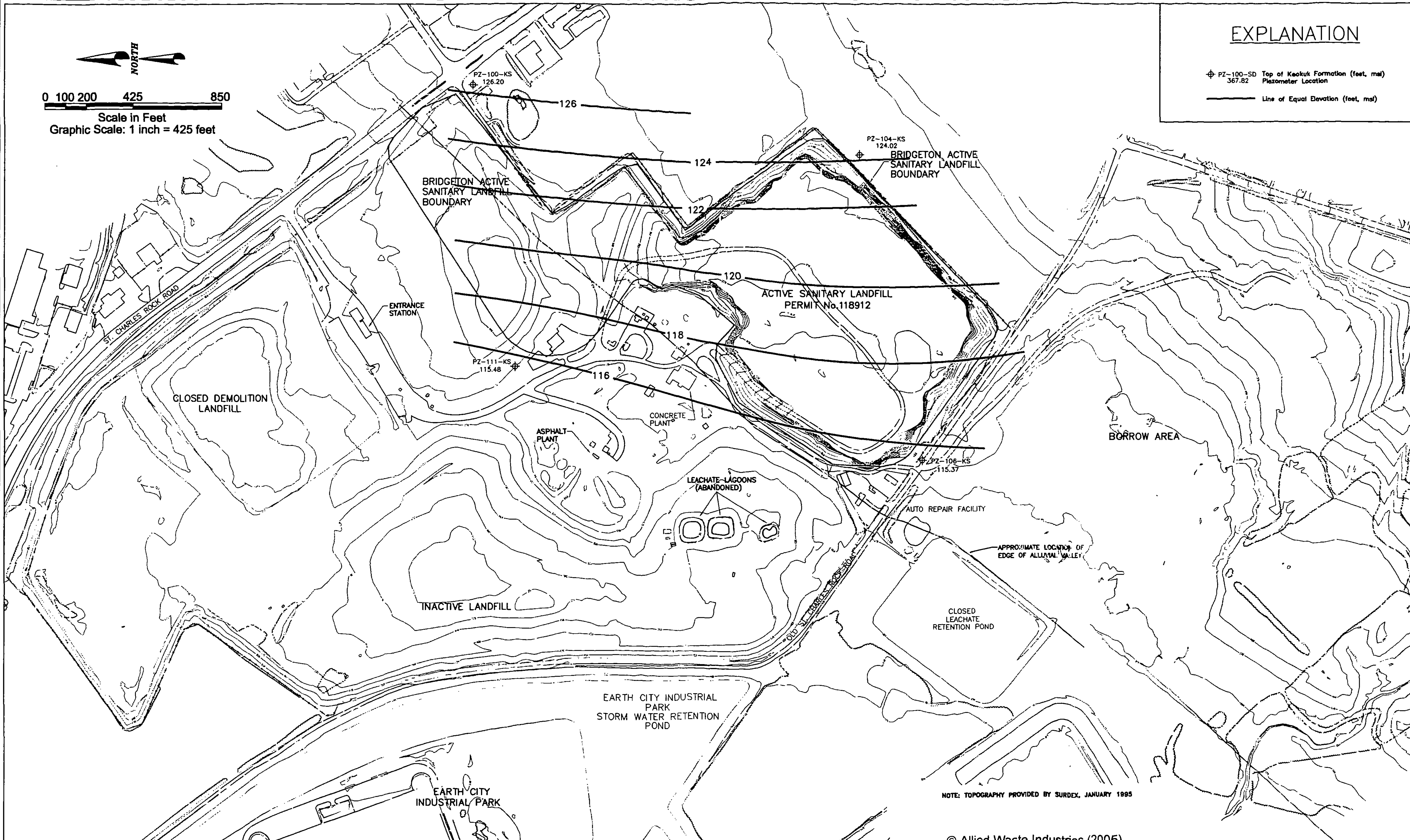

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Figure 3-8
Structural Contour Map
Keokuk Formation Surface

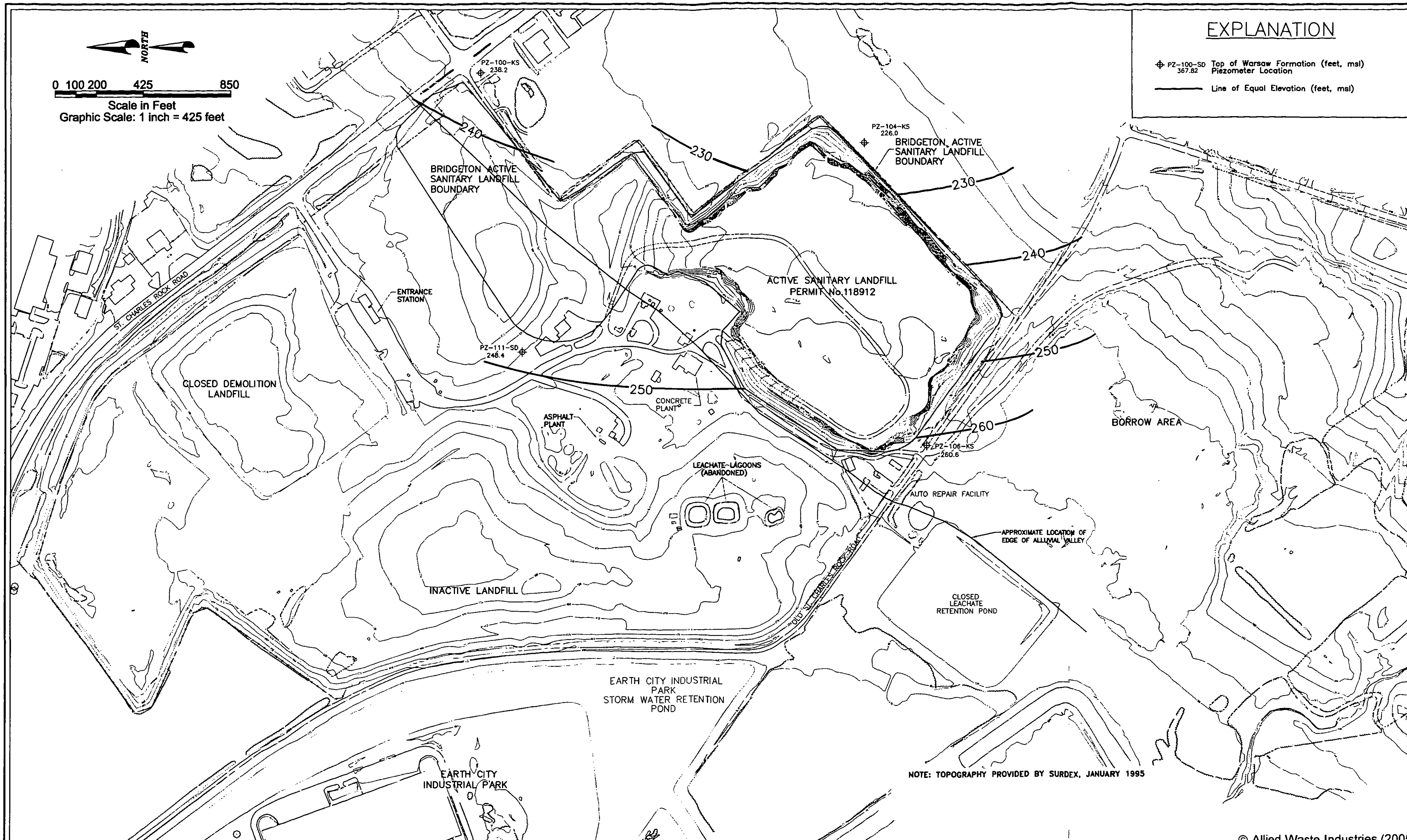

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Figure 3-9
Structural Contour Map
Warsaw Formation Surface

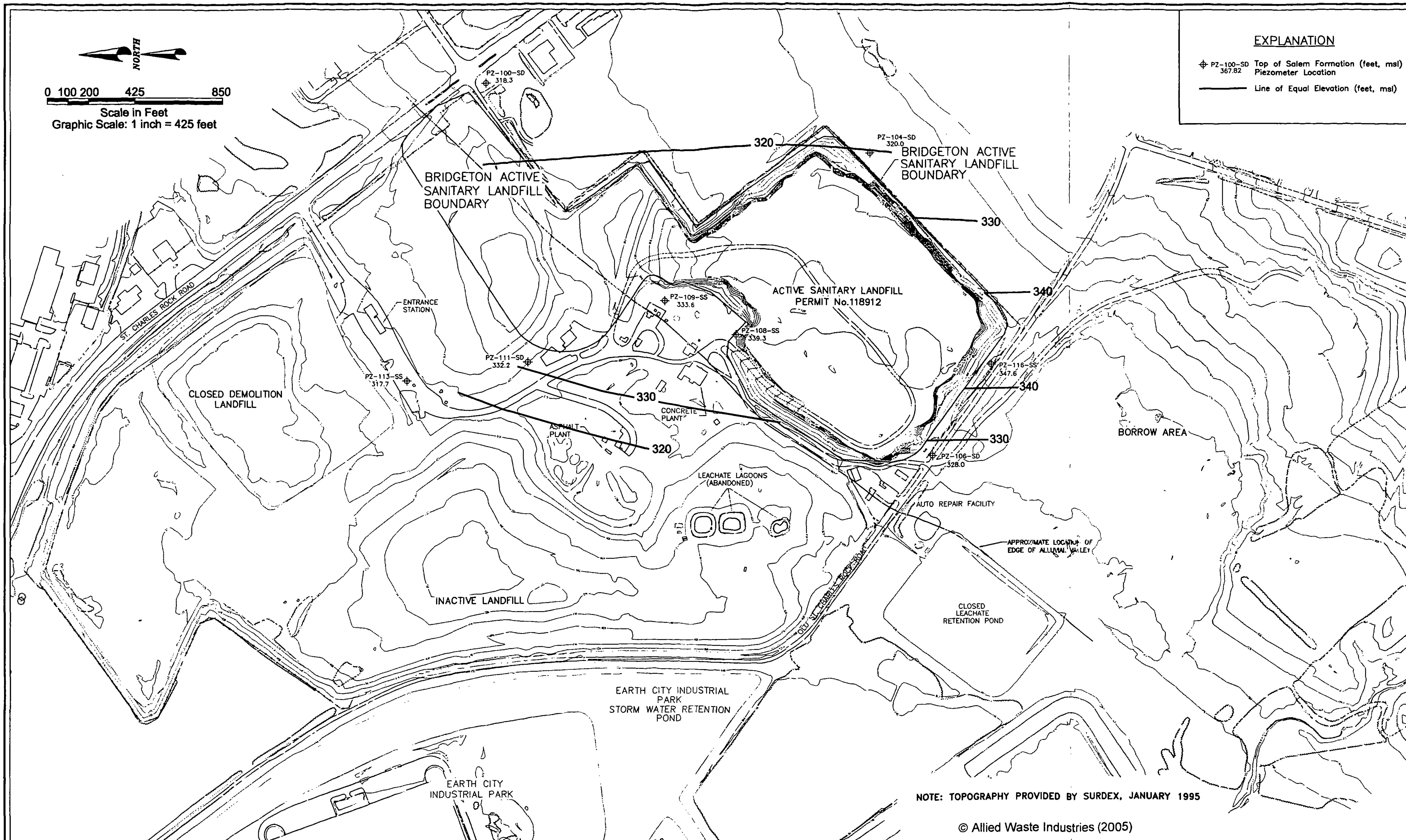

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Figure 3-10
Structural Contour Map
Salem Formation Surface

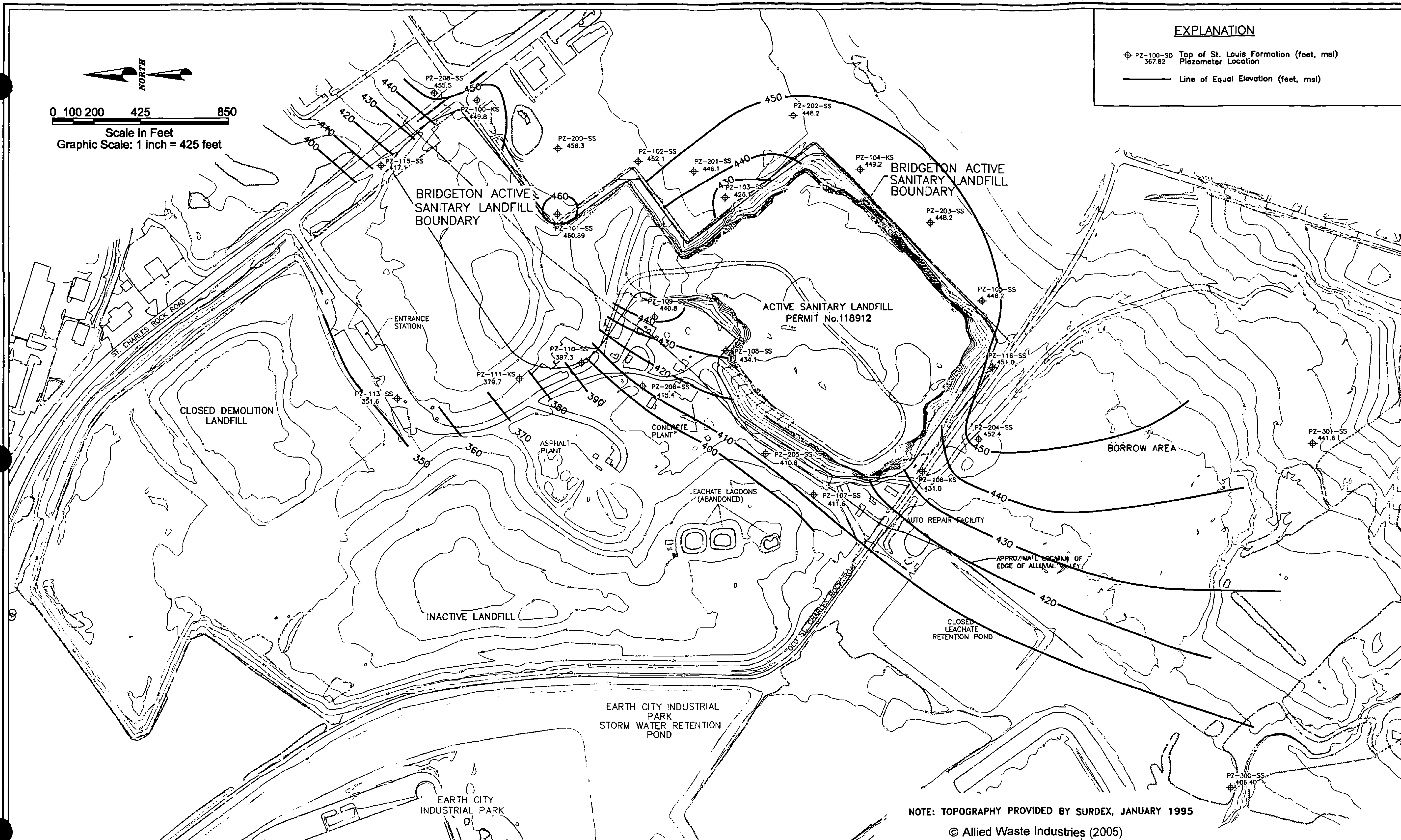

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Figure 3-11
Structural Contour Map
St. Louis Formation Surface

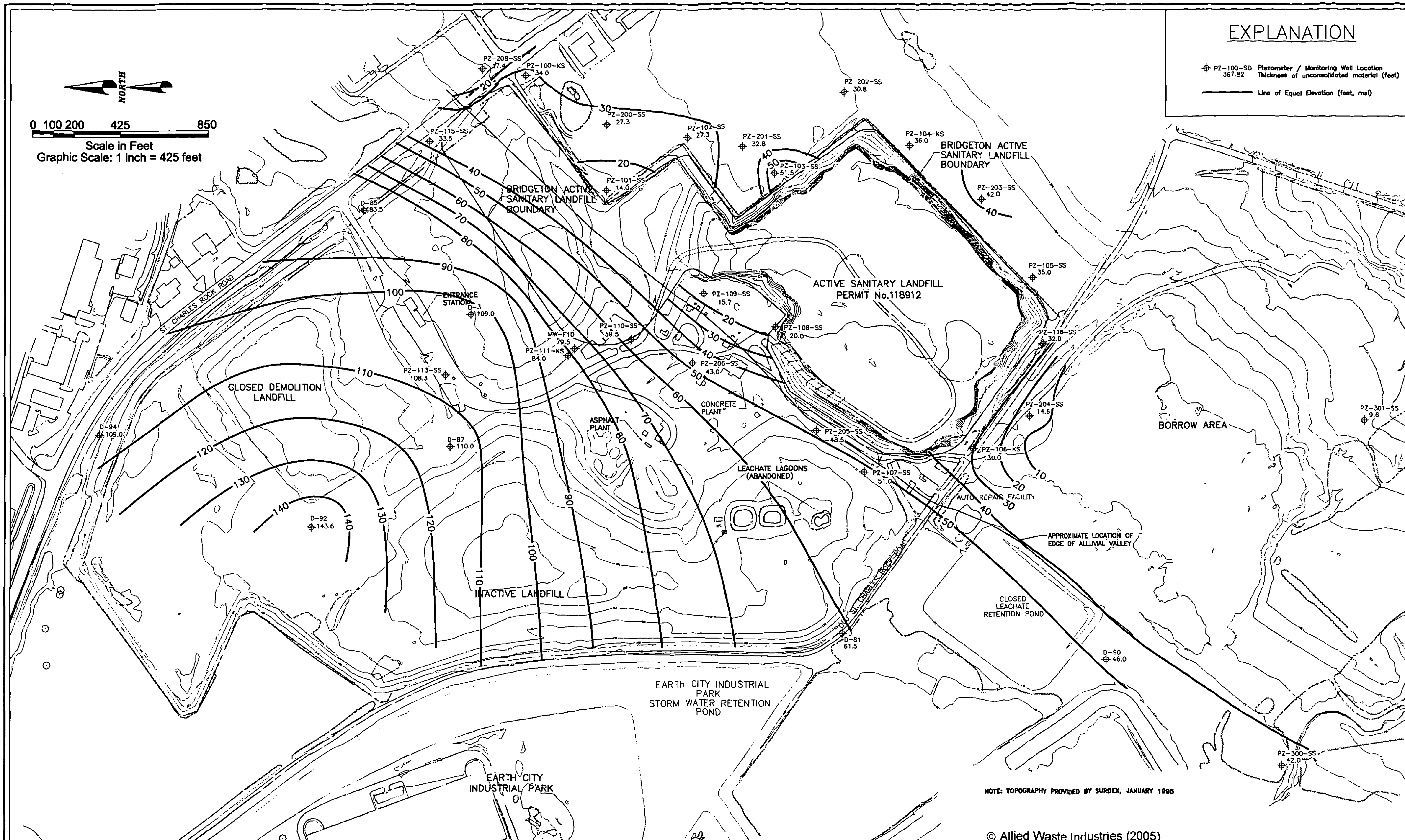

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Figure 3-12
Isopach Map of Unconsolidated Materials

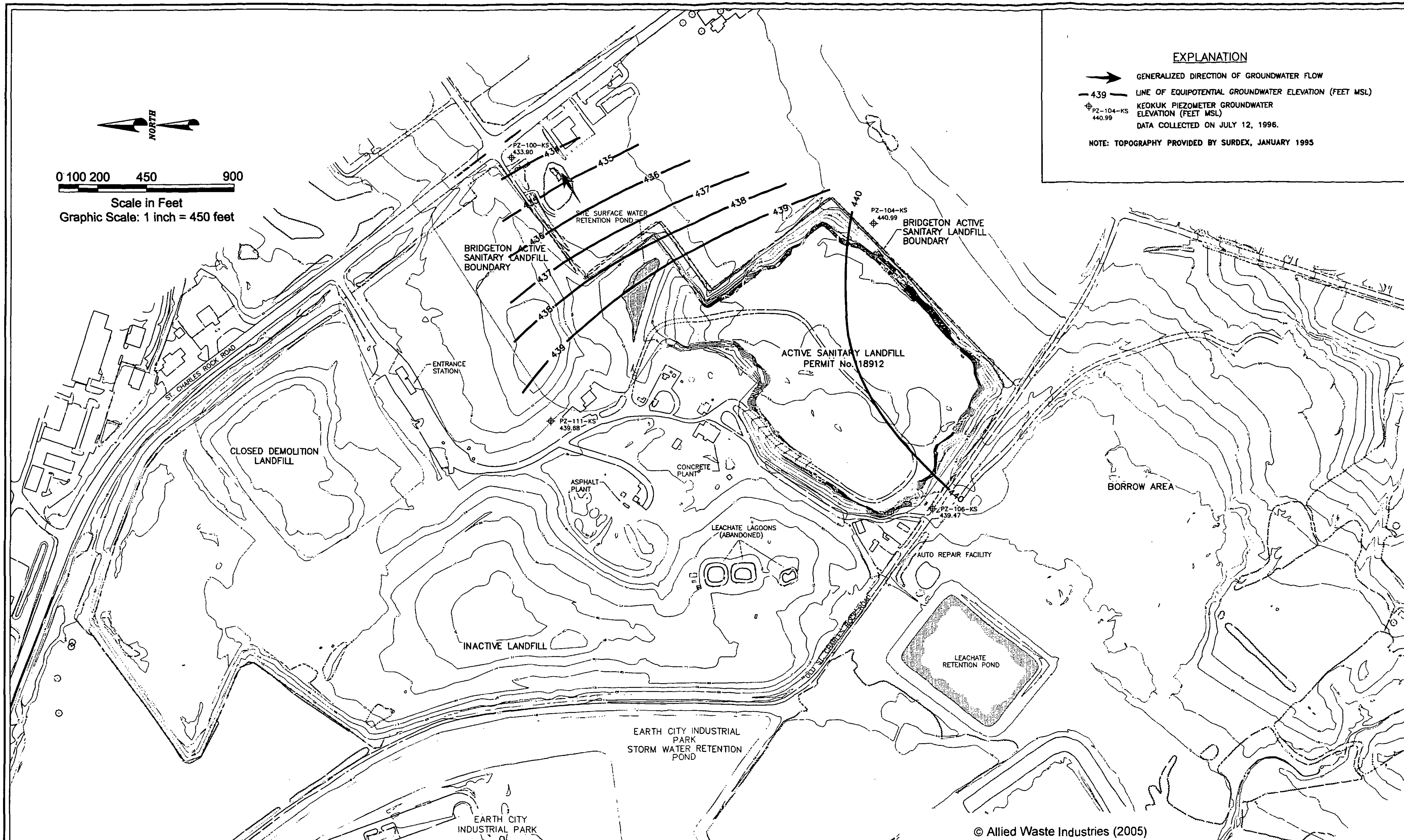

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Figure 3-13
Keokuk Hydrologic Unit
October 28, 1995
Potentiometric Surface Map

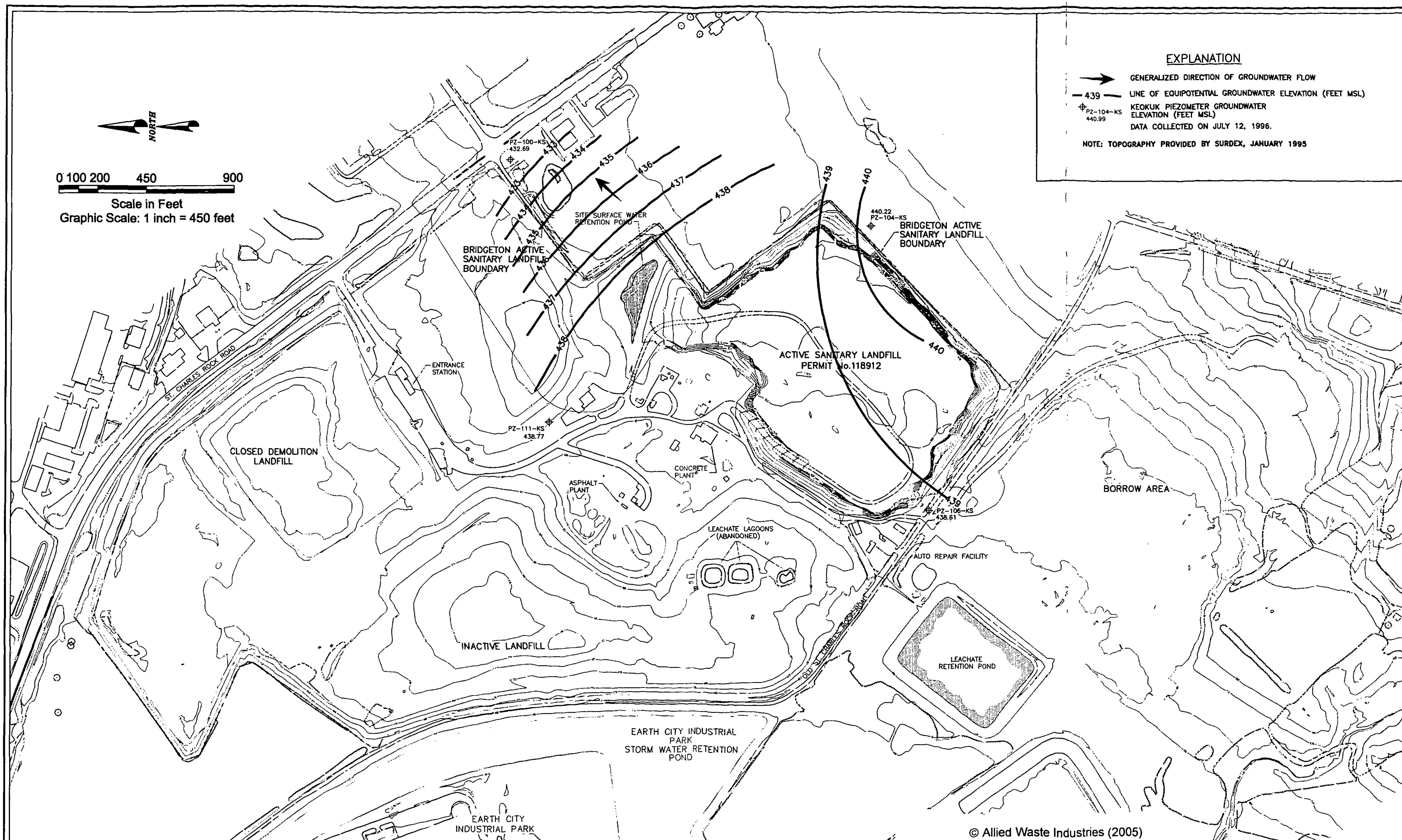

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Figure 3-14
Keokuk Hydrologic Unit
January 4, 1996
Potentiometric Surface Map

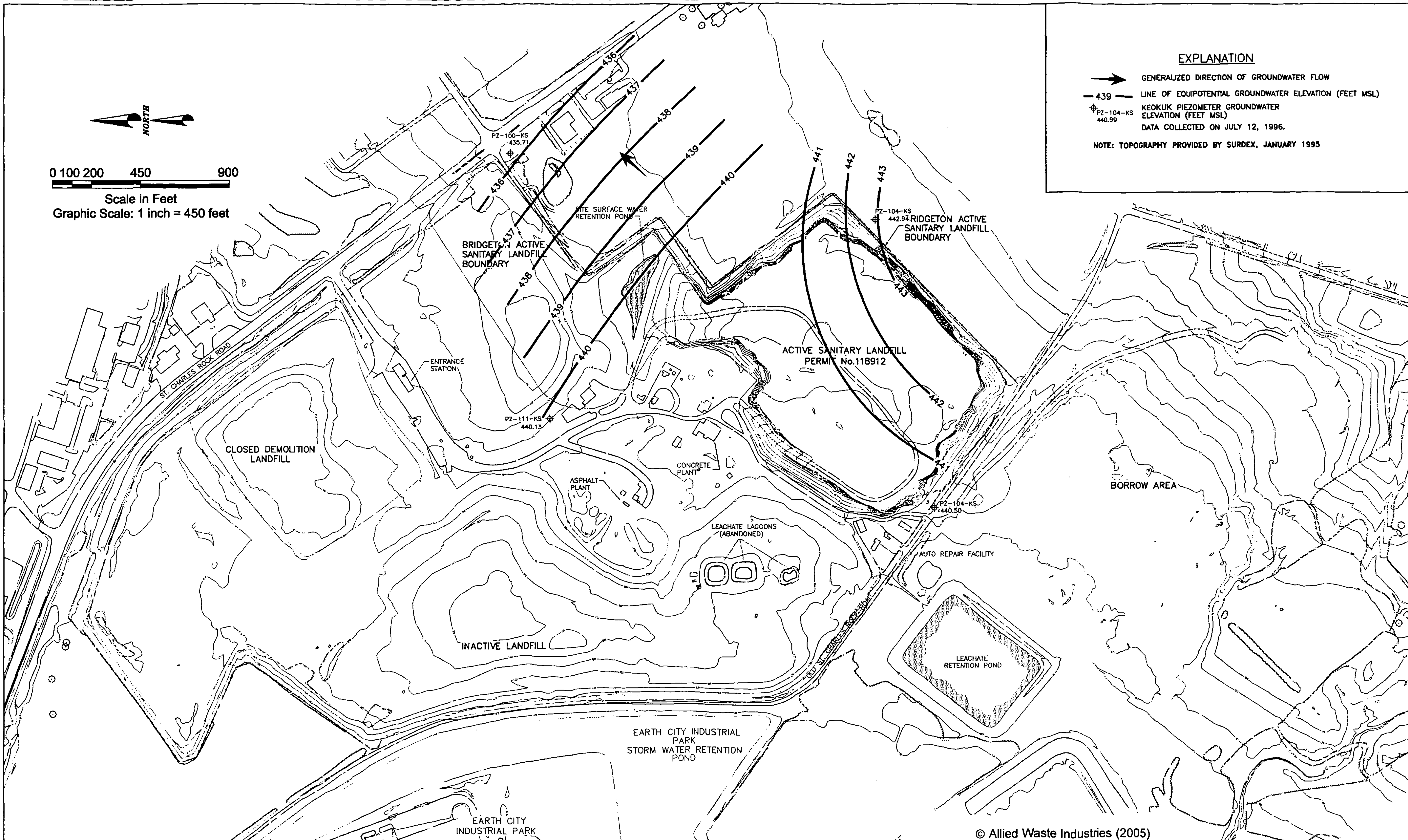

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Figure 3-15
Keokuk Hydrologic Unit
Potentiometric Surface Map
April 3, 1996

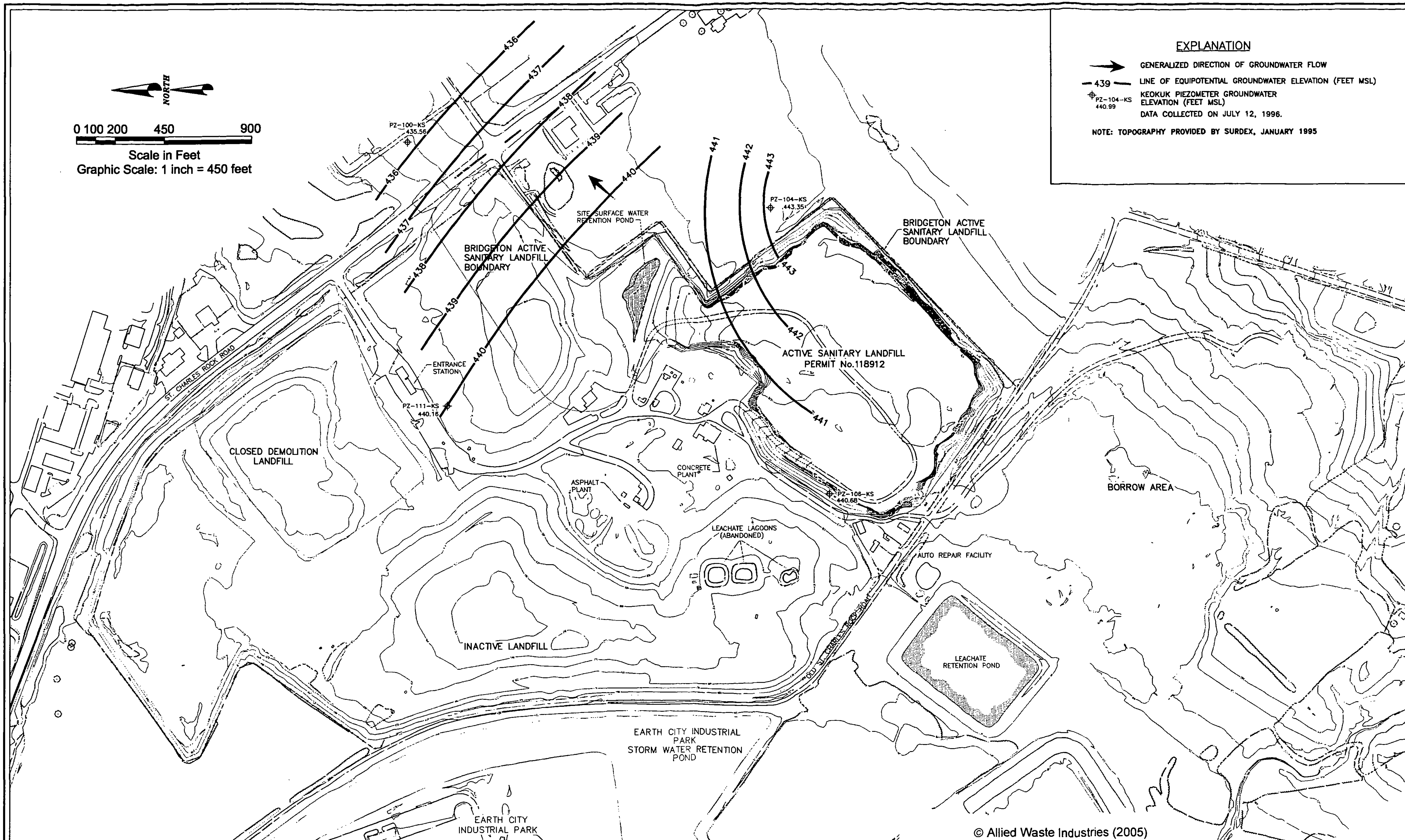

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Figure 3-16
Keokuk Hydrologic Unit
May 3, 1996
Potentiometric Surface Map

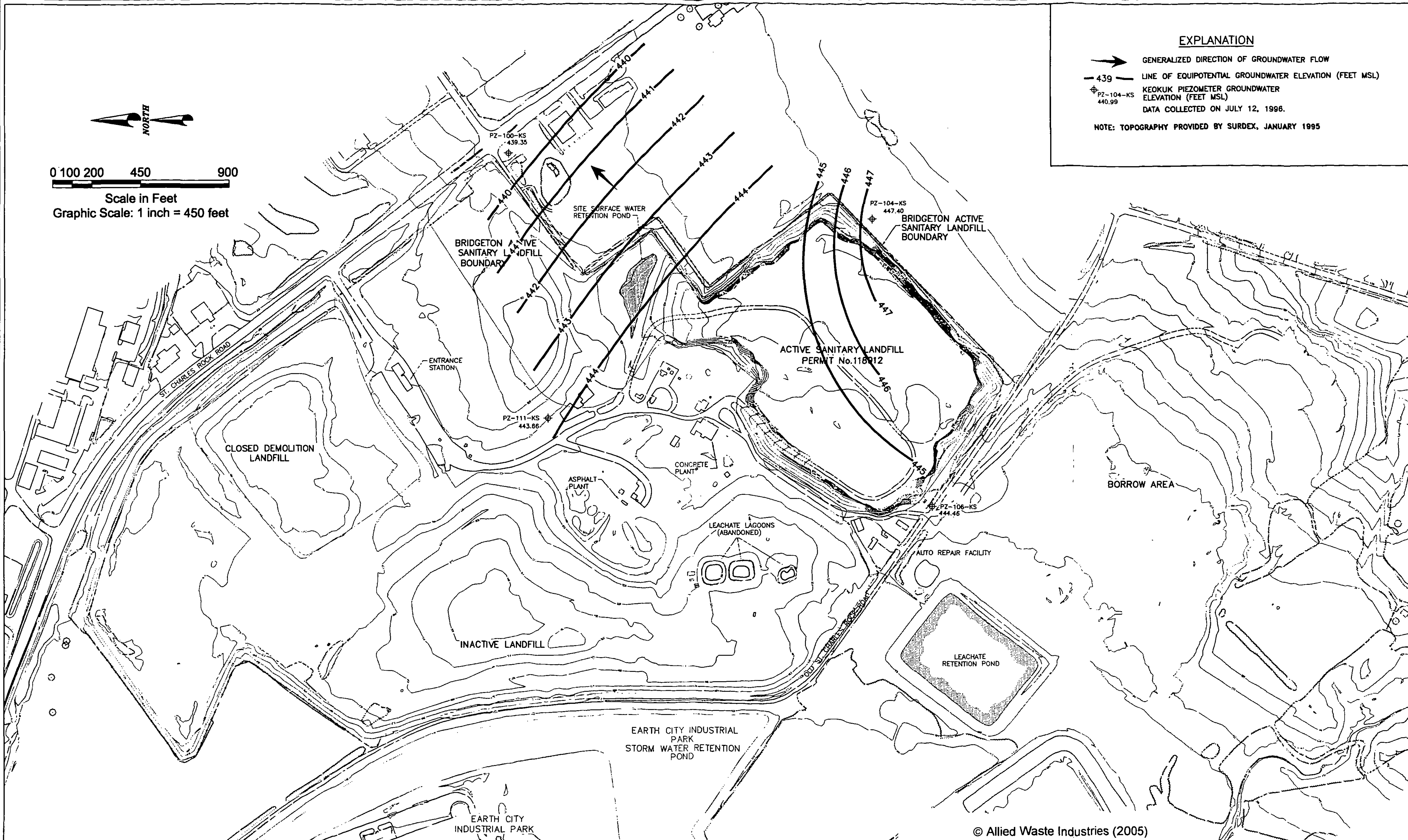

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Figure 3-17
Keokuk Hydrologic Unit
July 12, 1996
Potentiometric Surface Map

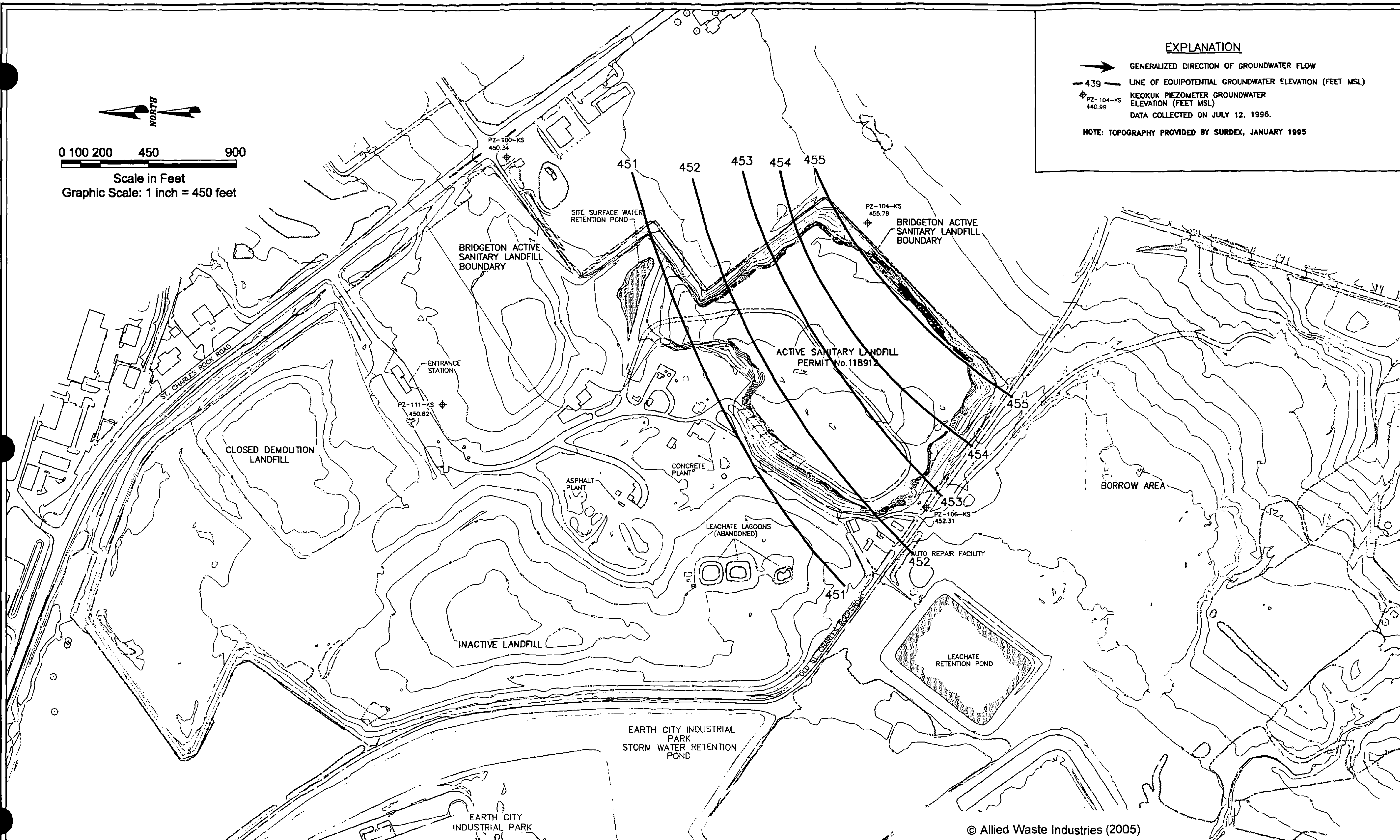

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Figure 3-18
Keokuk Hydrologic Unit
May 22, 2000
Potentiometric Surface Map

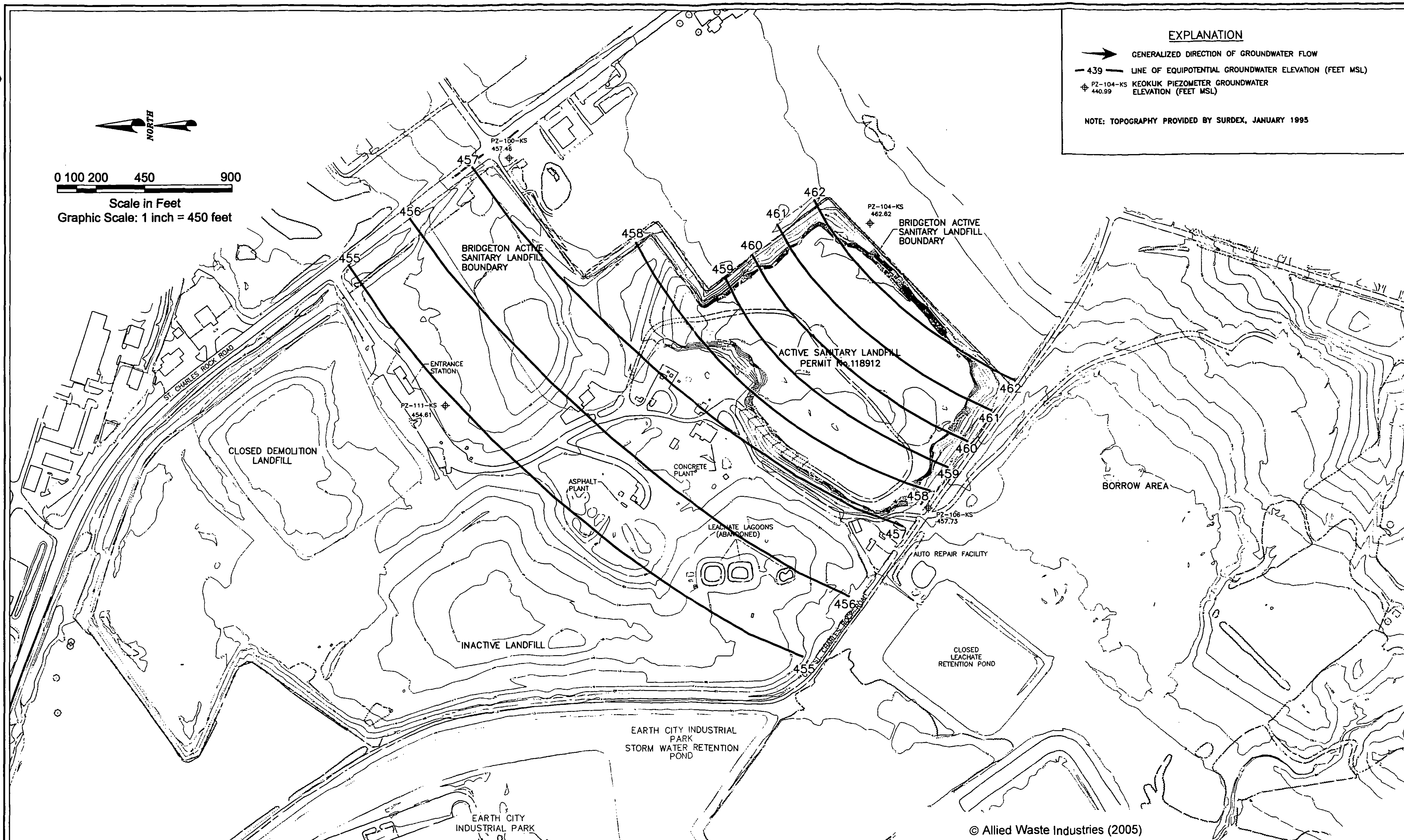

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Figure 3-19
Keokuk Hydrologic Unit
November 19, 2003
Potentiometric Surface Map

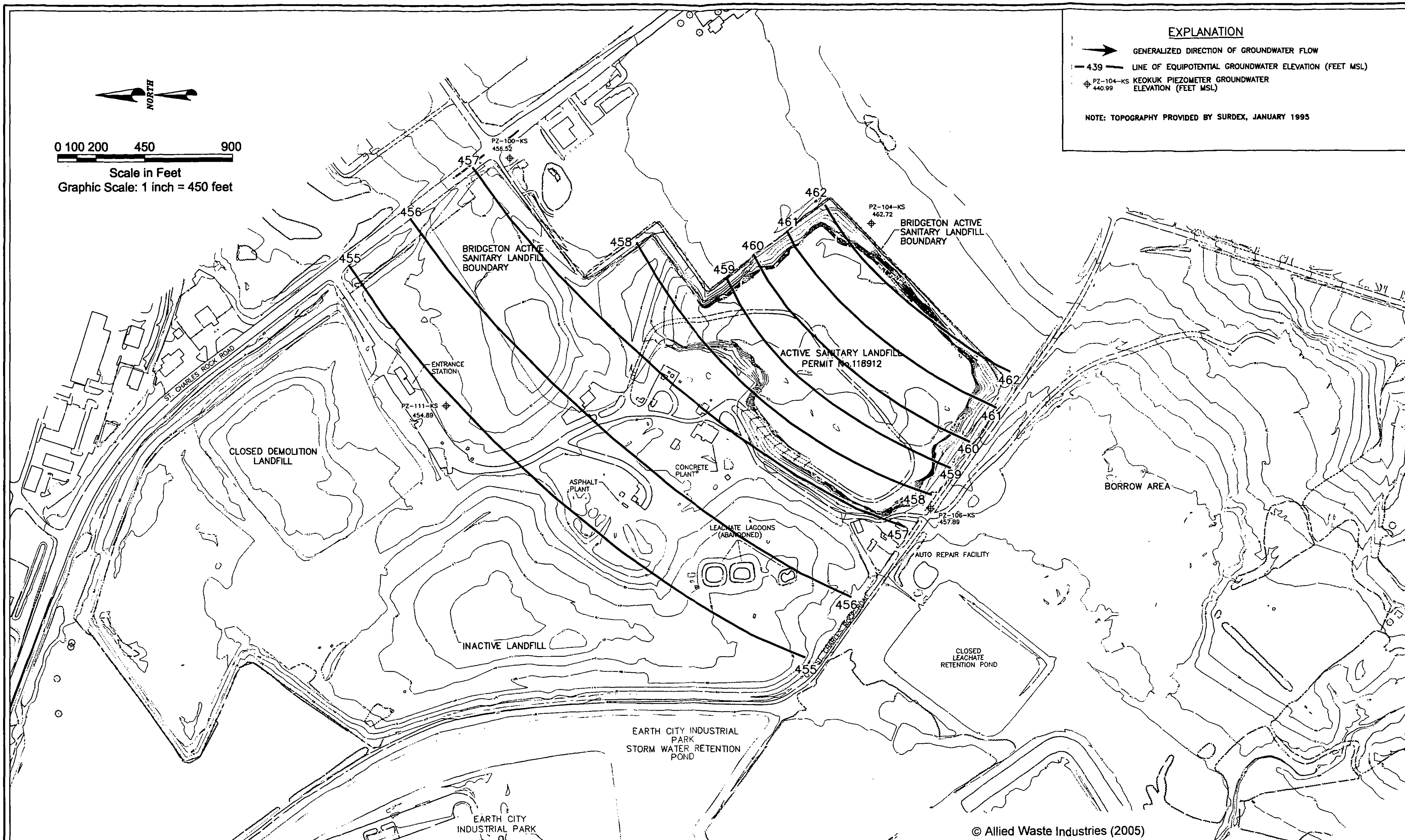

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Figure 3-20
Keokuk Hydrologic Unit
May 10, 2004
Potentiometric Surface Map

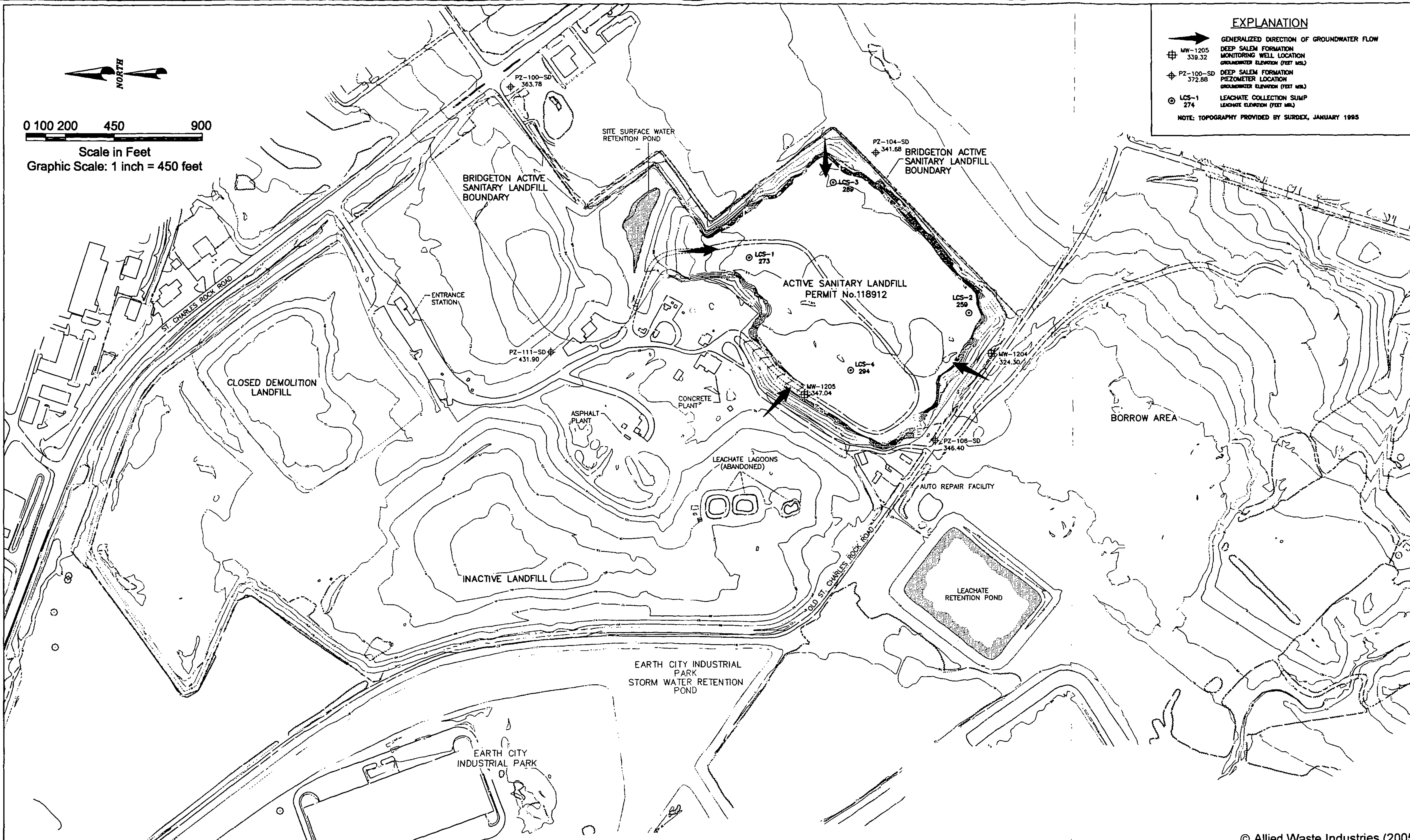

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Figure 3-21
Deep Salem Hydrologic Unit
October 28, 1995
Potentiometric Surface Map

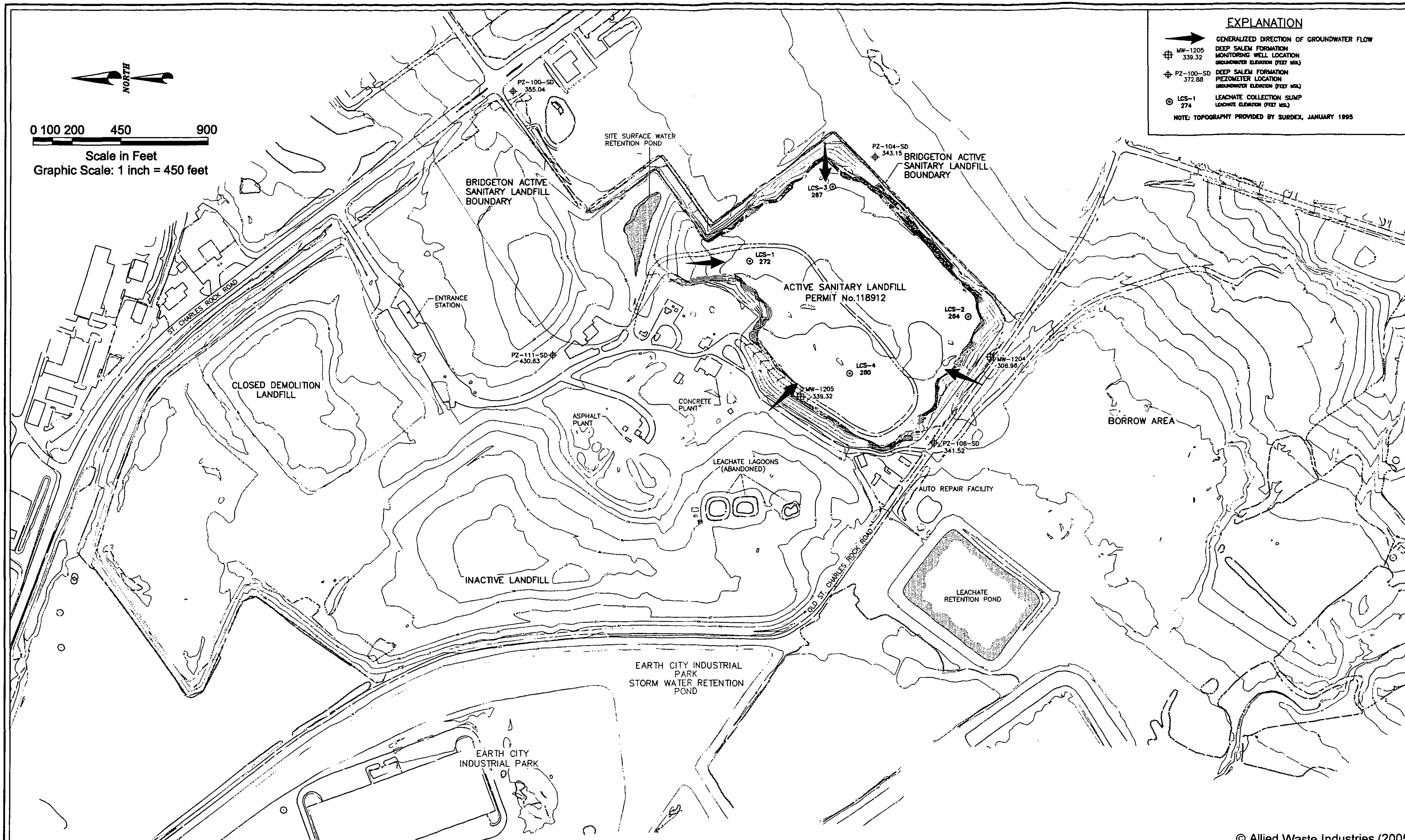

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Figure 3-22
Deep Salem Hydrologic Unit
January 4, 1996
Potentiometric Surface Map

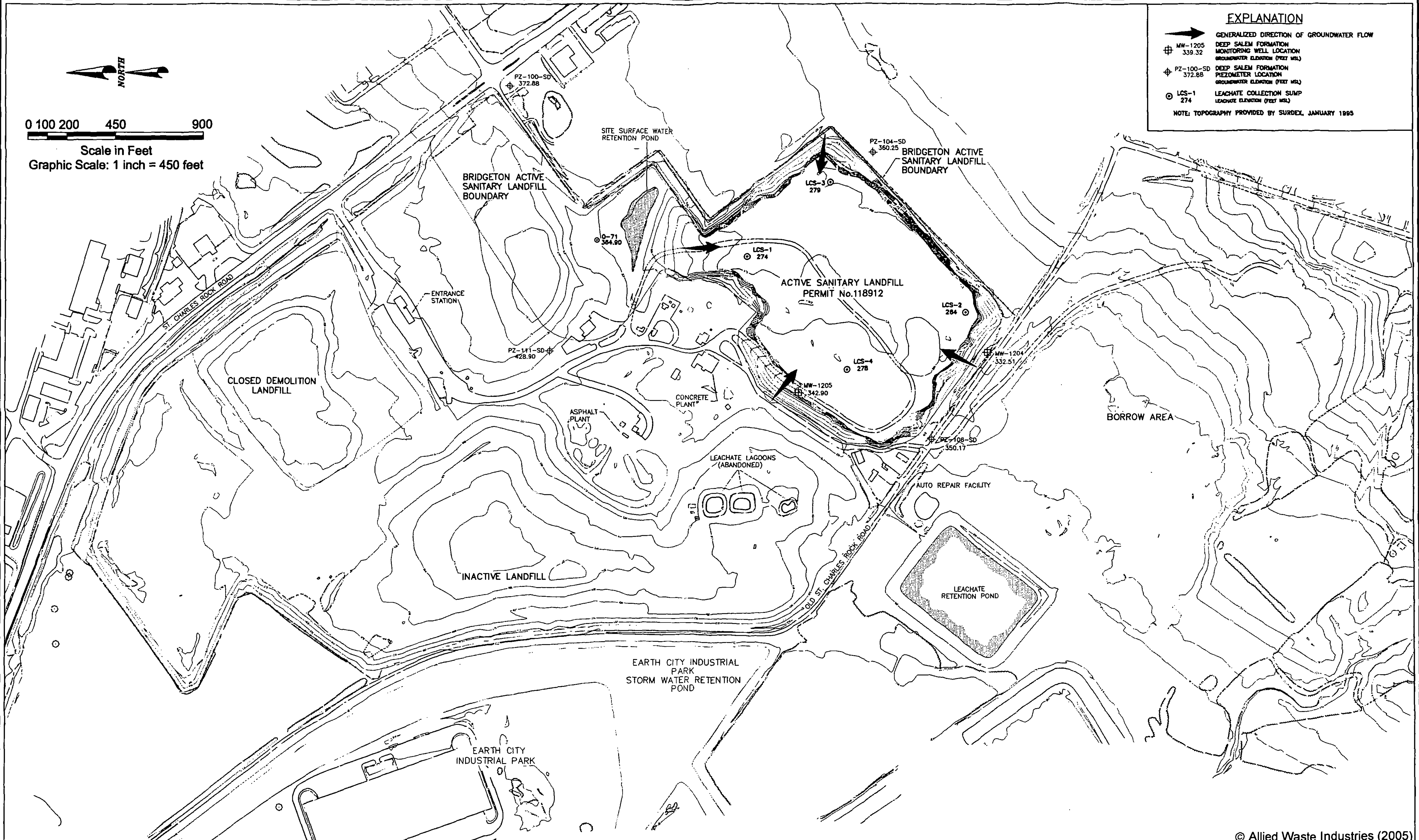

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Figure 3-23
Deep Salem Hydrologic Unit
April 3, 1996

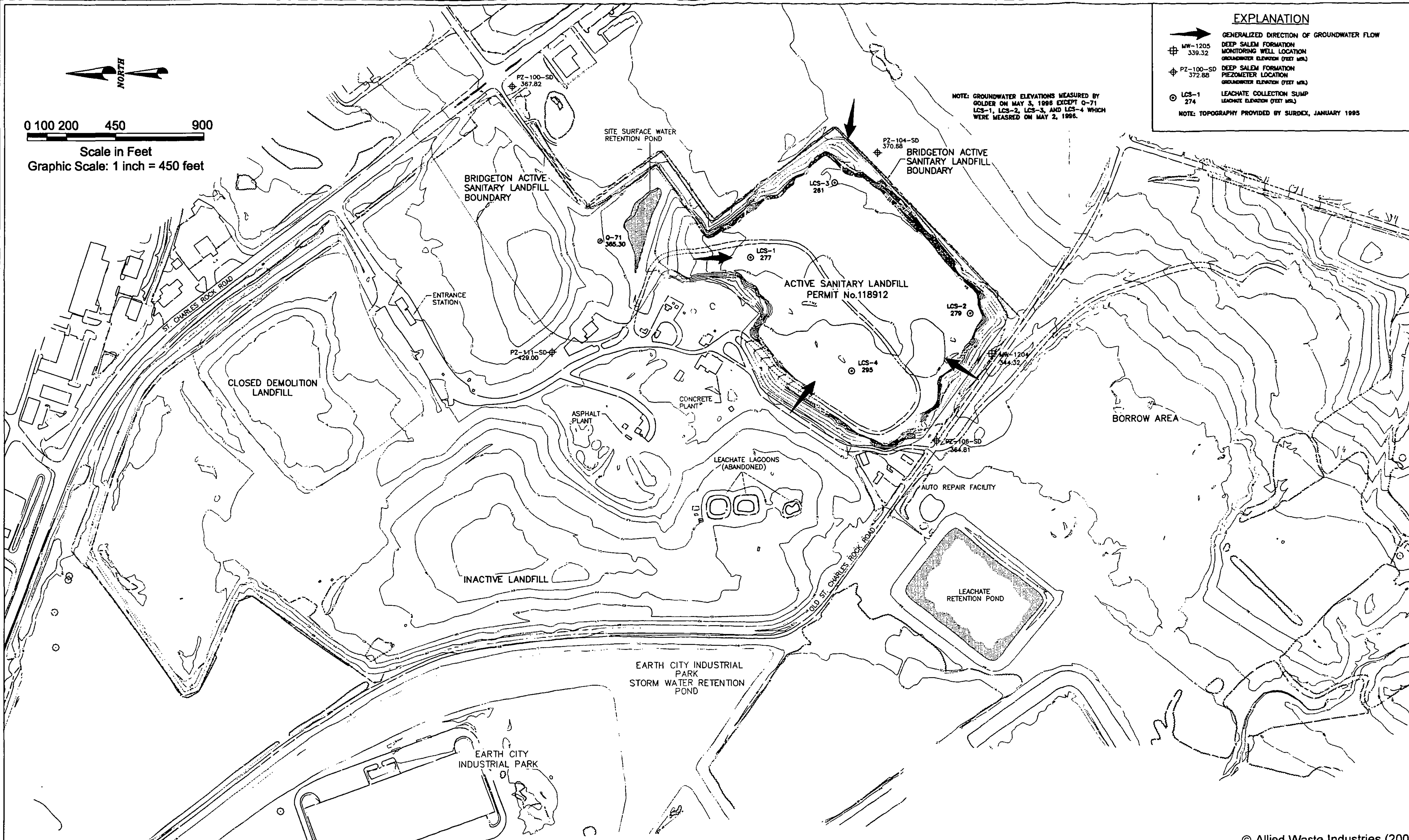

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Figure 3-24
Deep Salem Hydrologic Unit
May 3, 1996
Potentiometric Surface Map

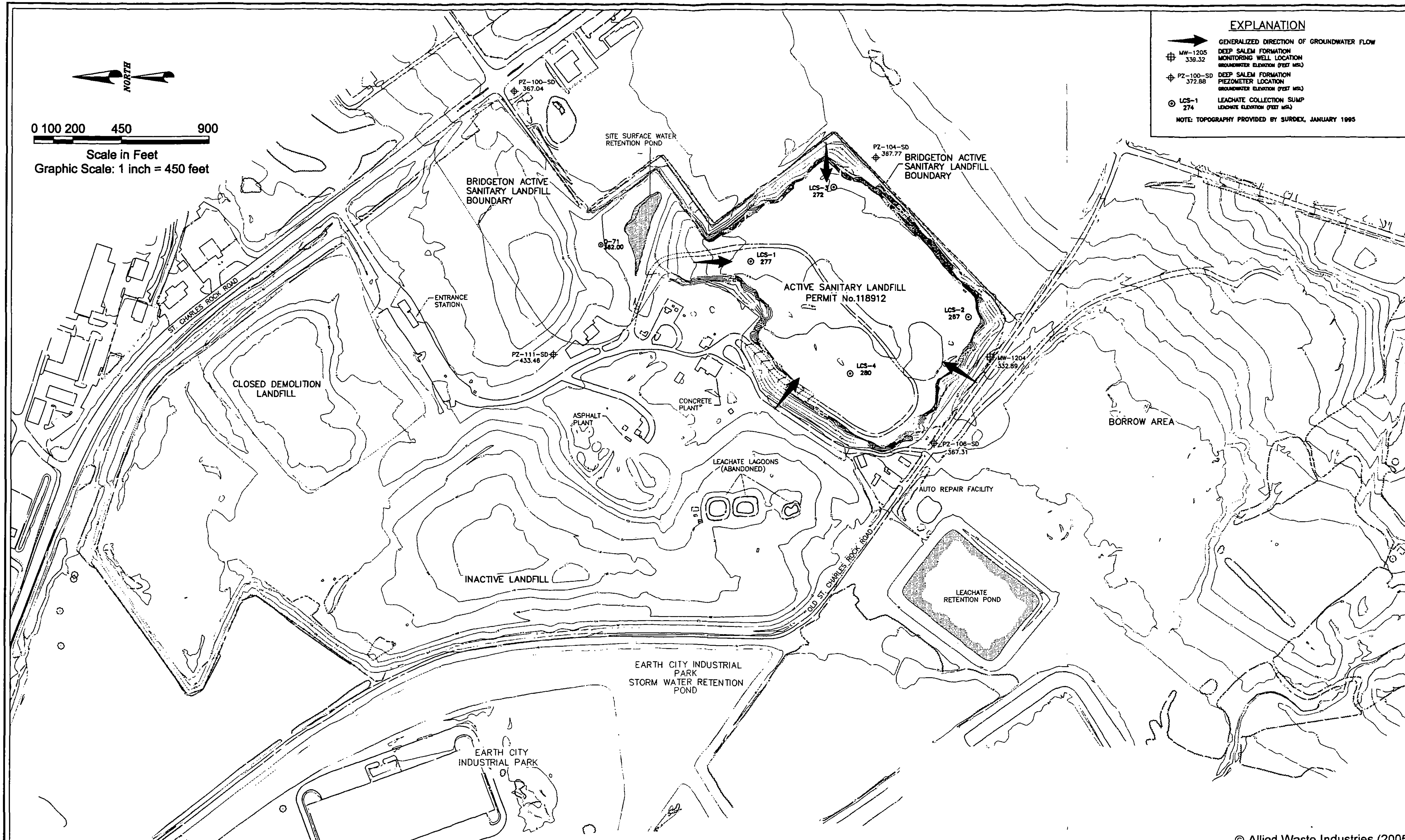

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Figure 3-25
Deep Salem Hydrologic Unit
July 12, 1996
Potentiometric Surface Map

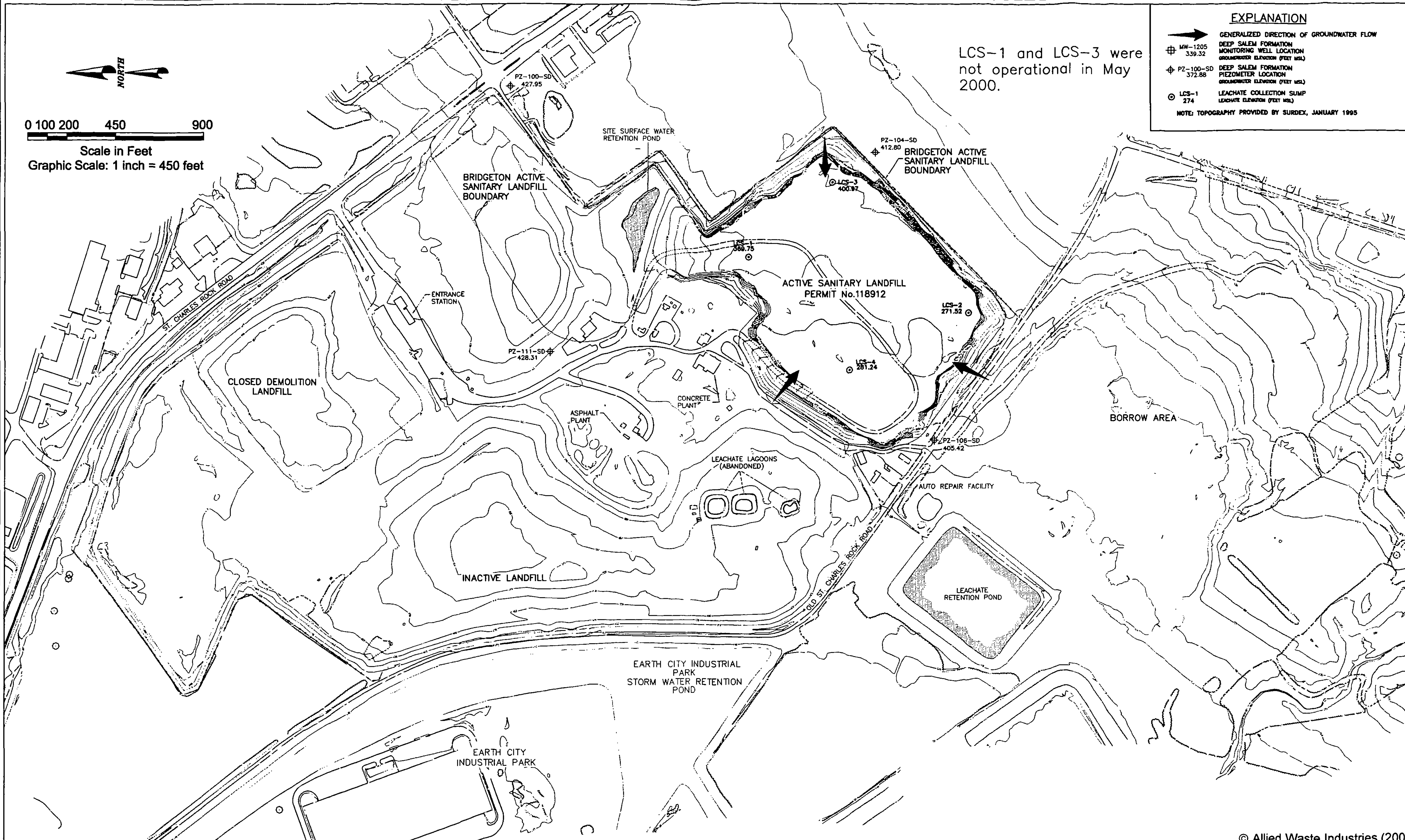

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Figure 3-26
Deep Salem Hydrologic Unit
May 22, 2000
Potentiometric Surface Map

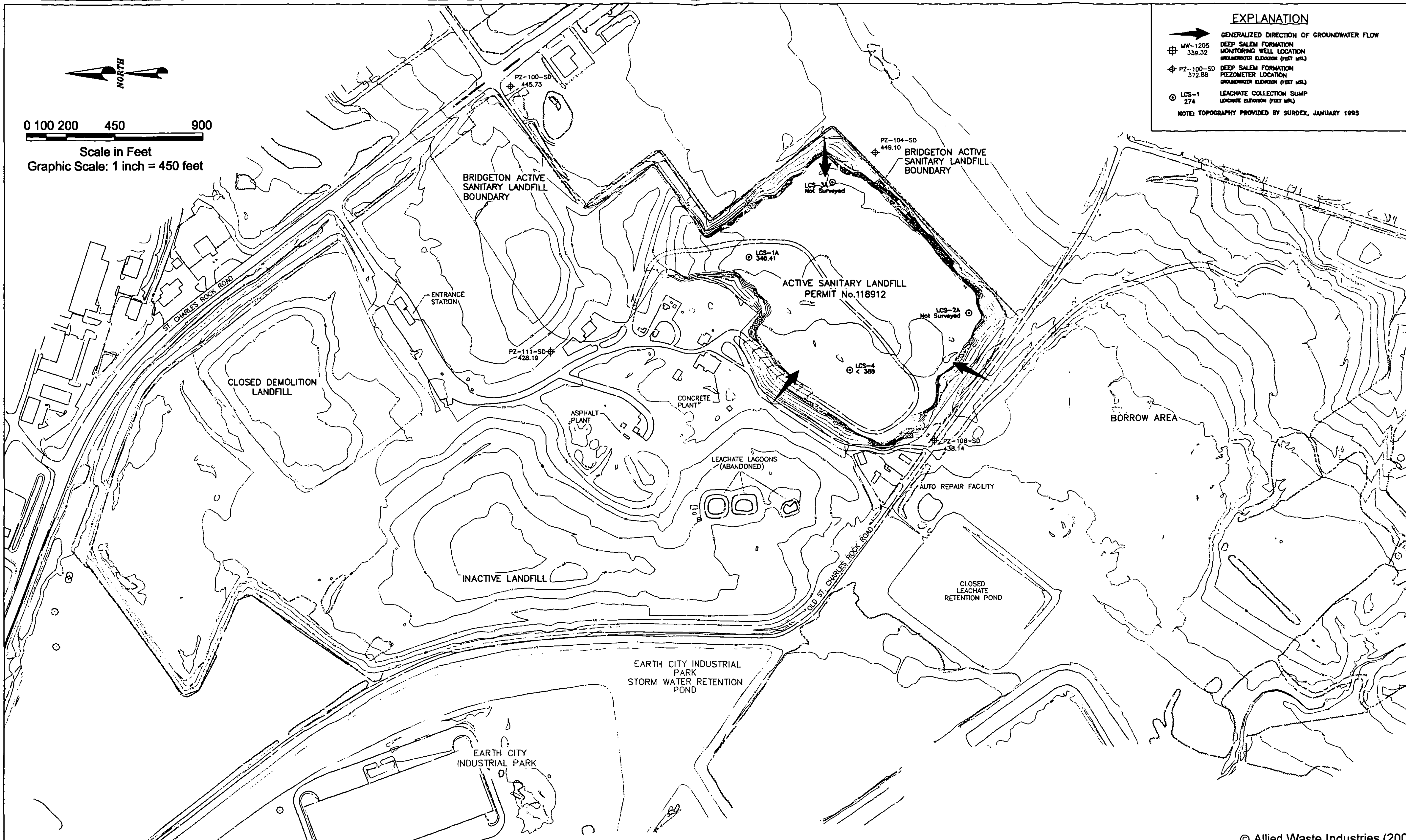

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Figure 3-27
Deep Salem Hydrologic Unit
November 19, 2003
Potentiometric Surface Map

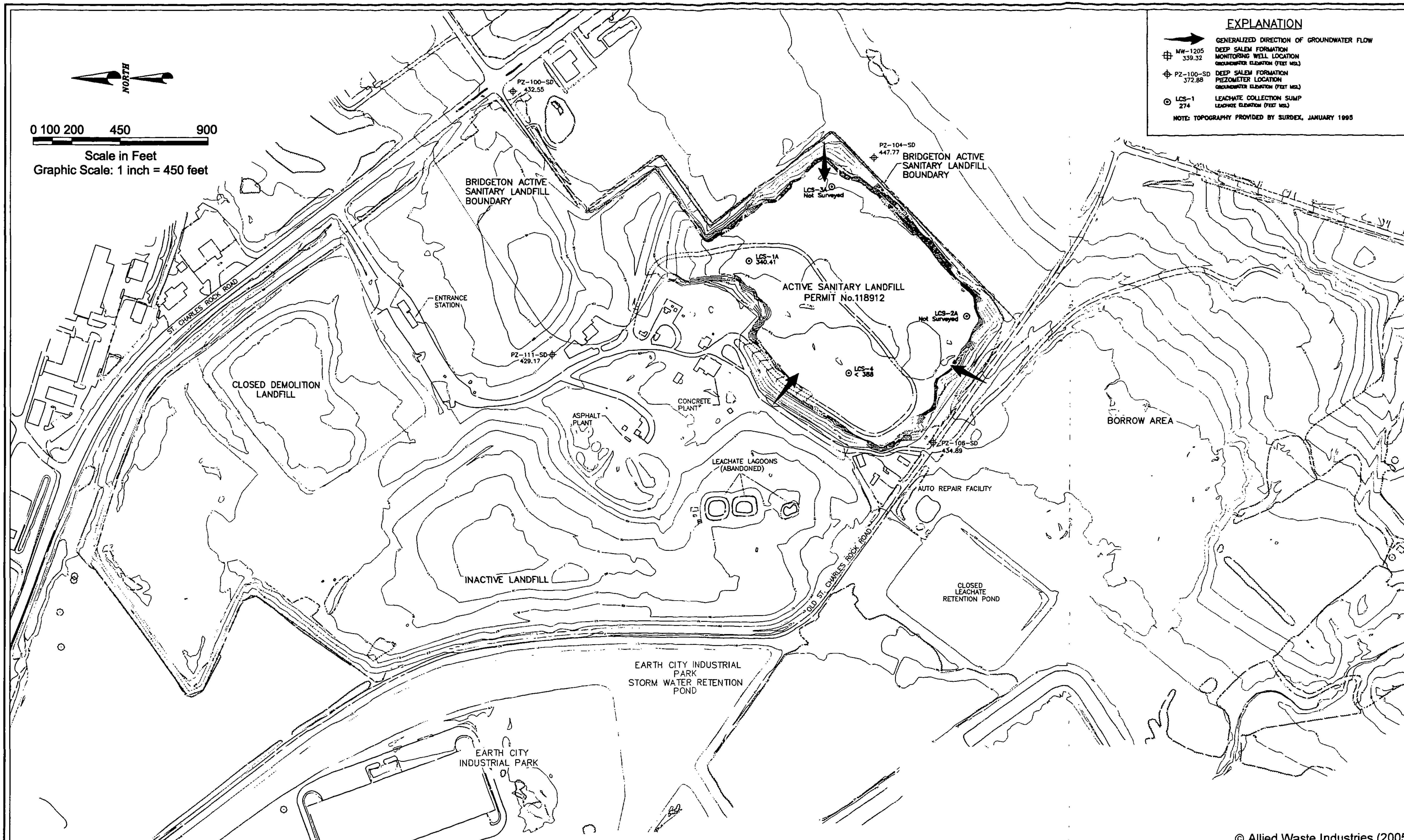

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Figure 3-28
Deep Salem Hydrologic Unit
May 10, 2004
Potentiometric Surface Map

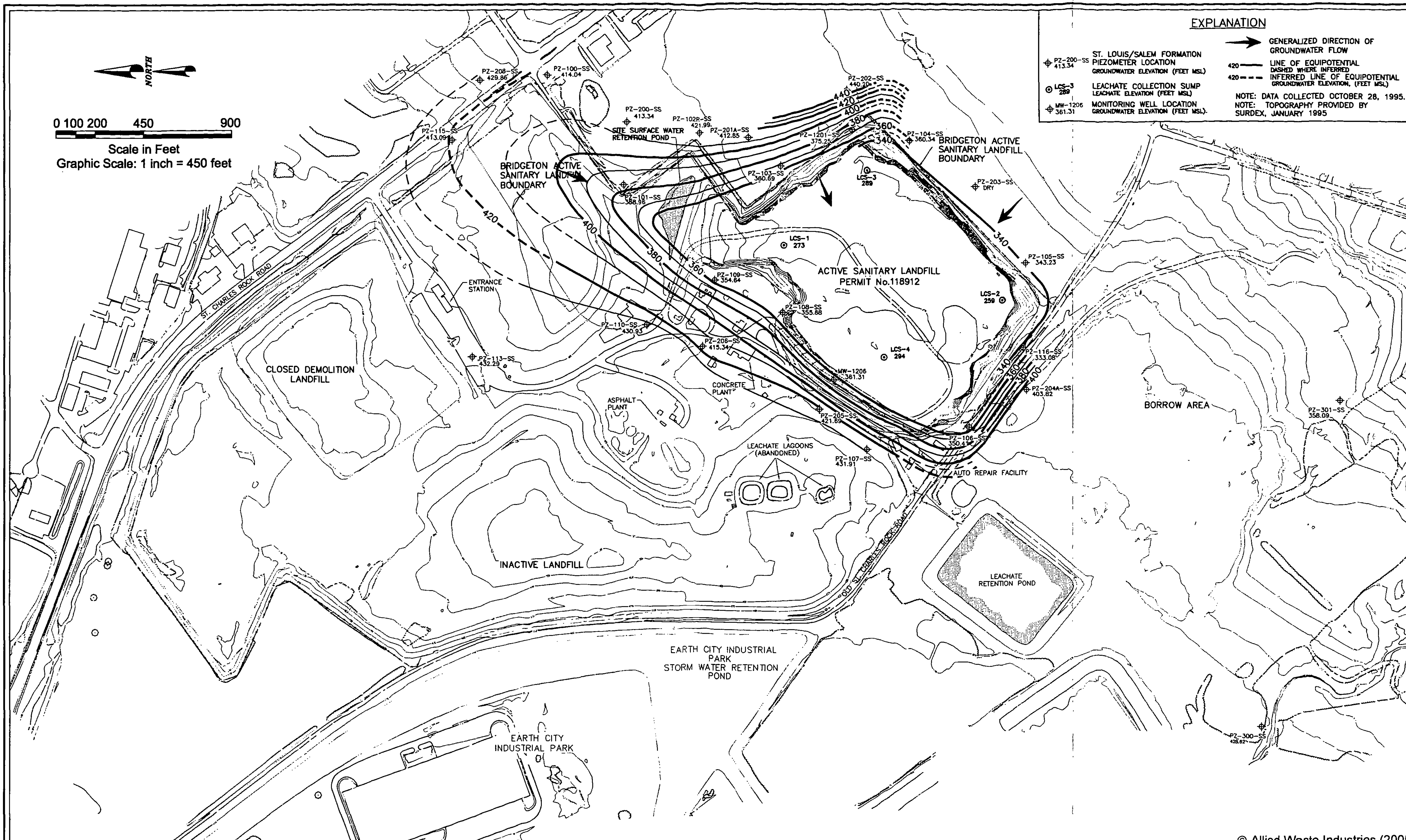

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Figure 3-29
St. Louis/Upper Salem Hydrologic Unit
October 28, 1995
Potentiometric Surface Map

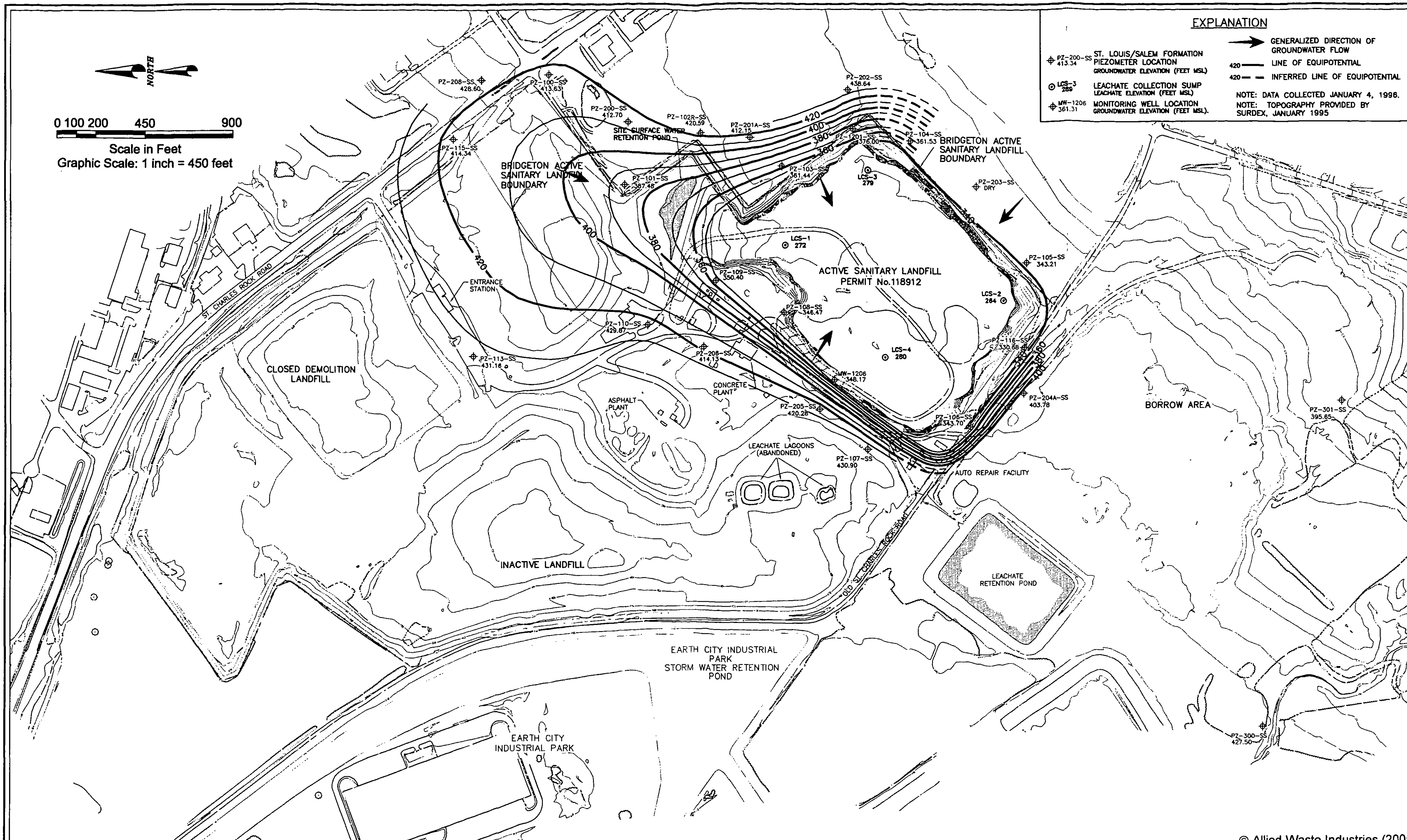

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Figure 3-30
St. Louis/Upper Salem Hydrologic Unit
January 4, 1996
Potentiometric Surface Map

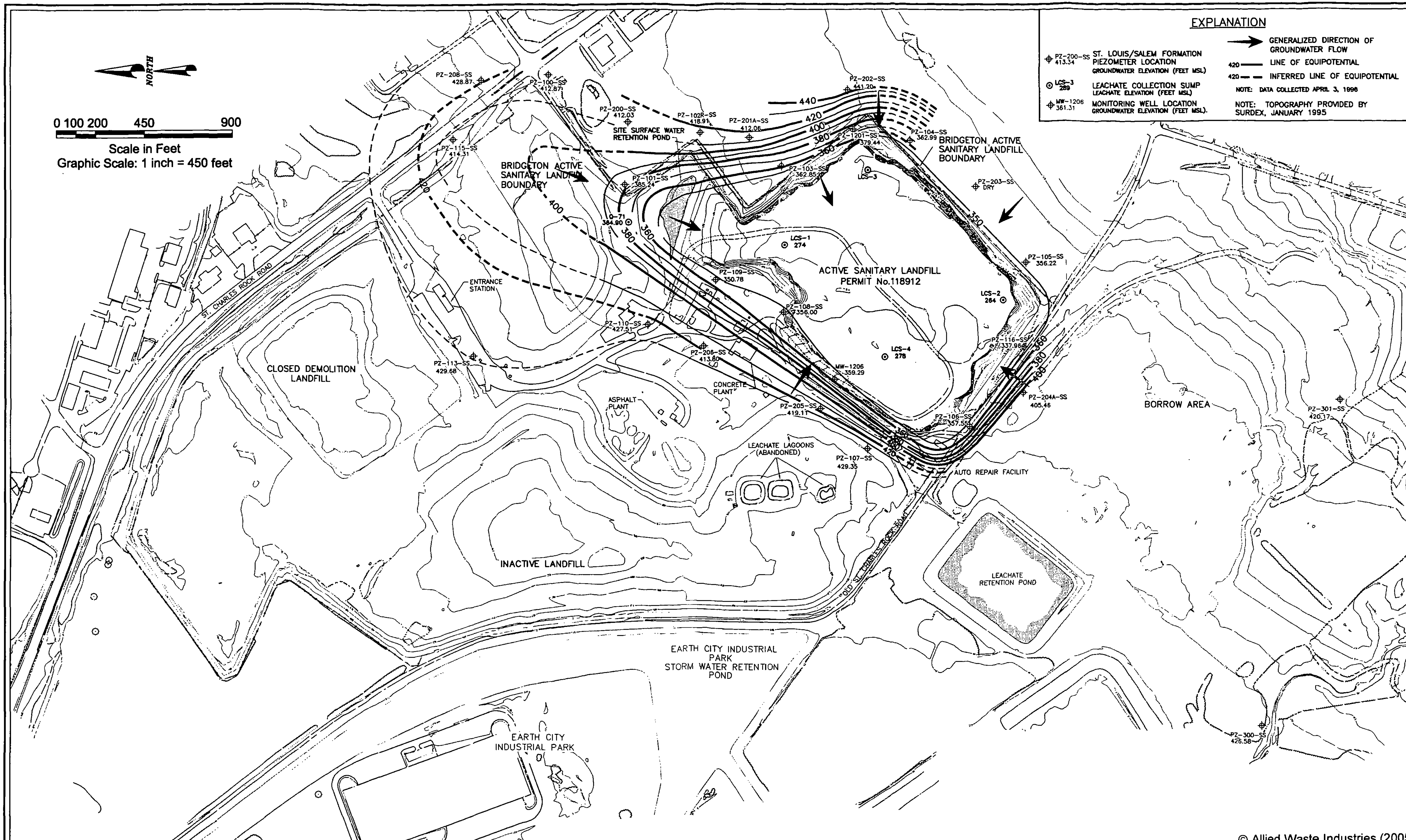

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Figure 3-31
St. Louis/Upper Salem Hydrologic Unit
April 27, 1996
Potentiometric Surface Map

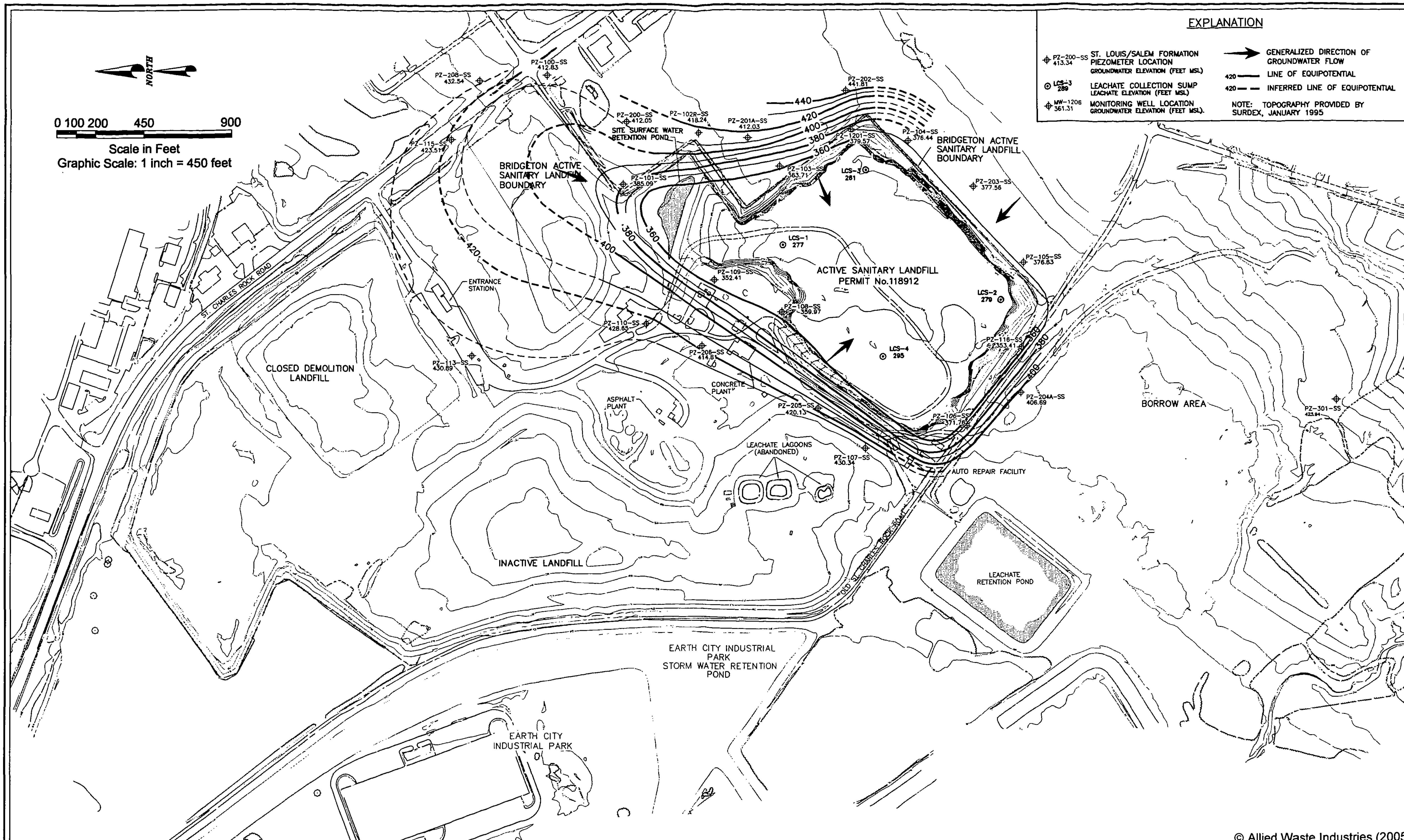

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Figure 3-32
St. Louis/Upper Salem Hydrologic Unit
May 3, 1996
Potentiometric Surface Map

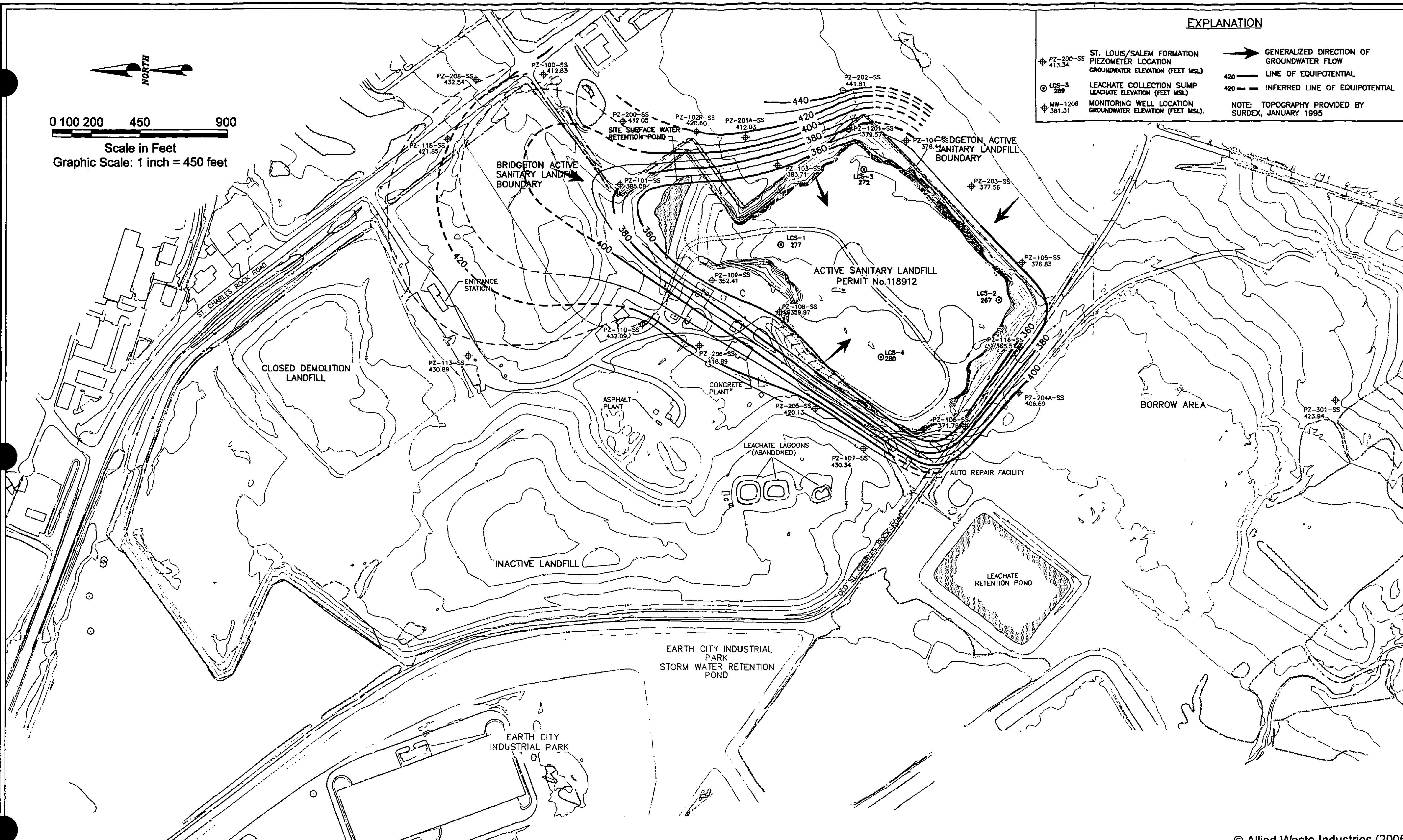

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Figure 3-33
St. Louis/Upper Salem Hydrologic Unit
July 12, 1996
Potentiometric Surface Map

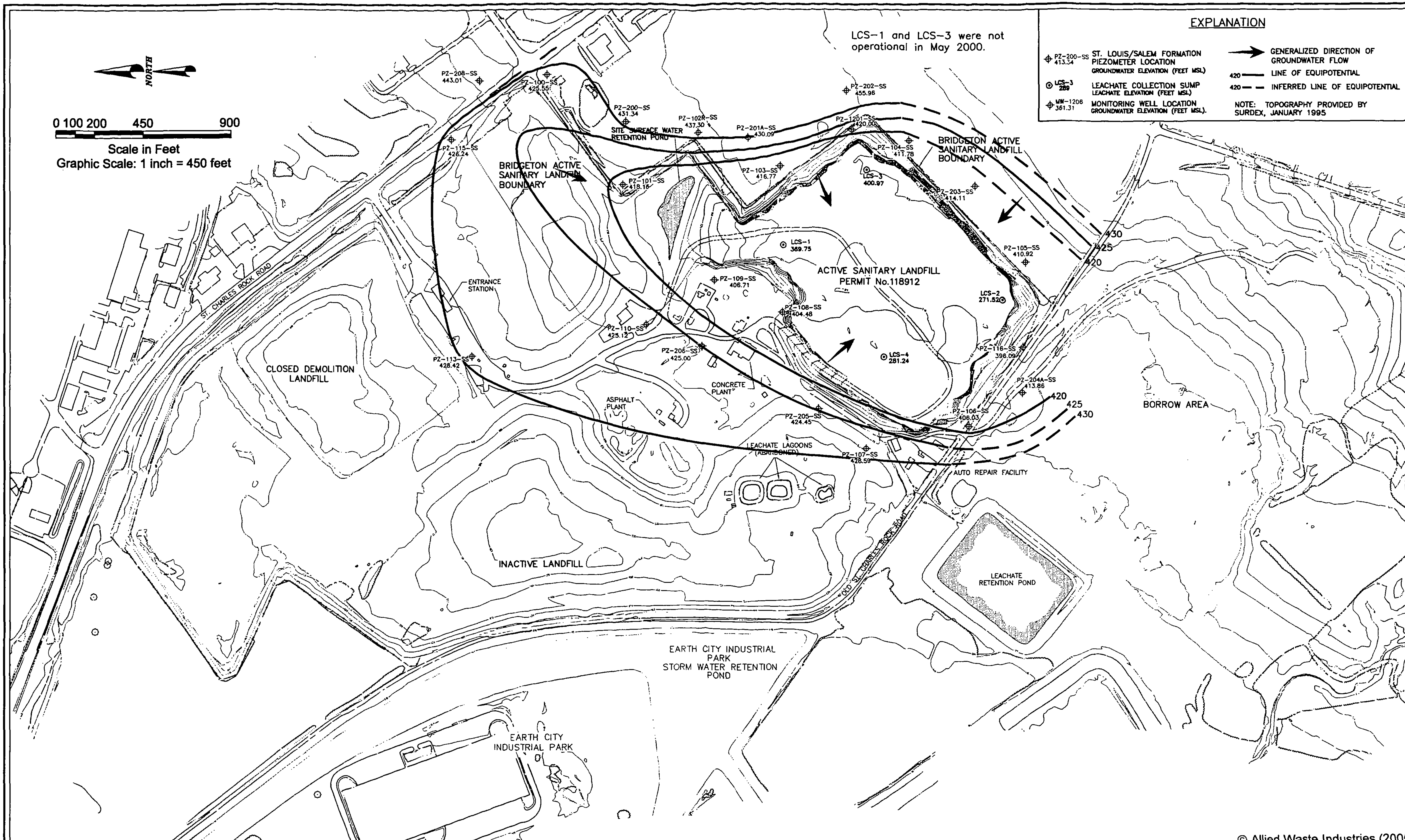

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Figure 3-34
St. Louis/Upper Salem Hydrologic Unit
May 22, 2000
Potentiometric Surface Map

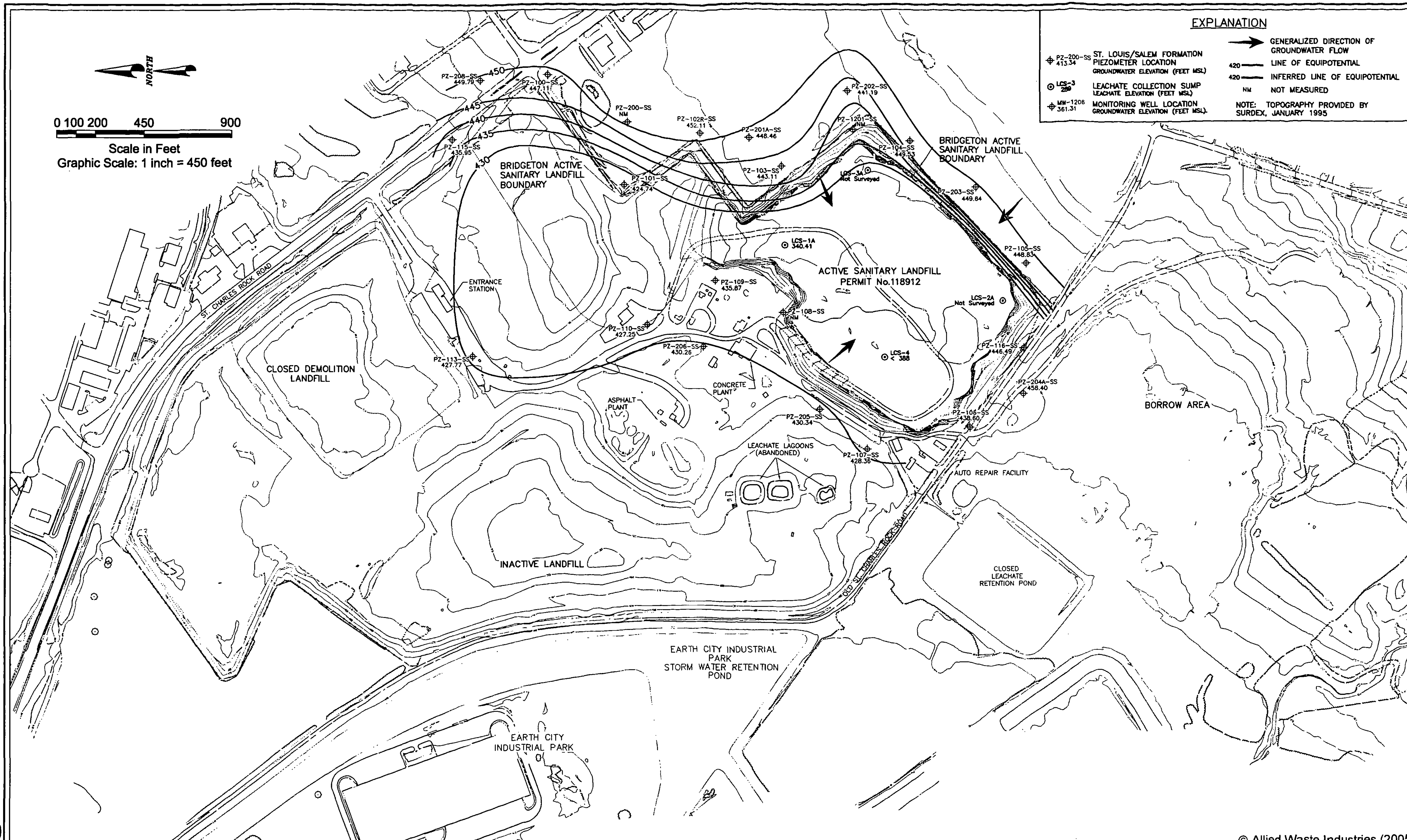

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Figure 3-35
St. Louis/Upper Salem Hydrologic Unit
November 19, 2003
Potentiometric Surface Map

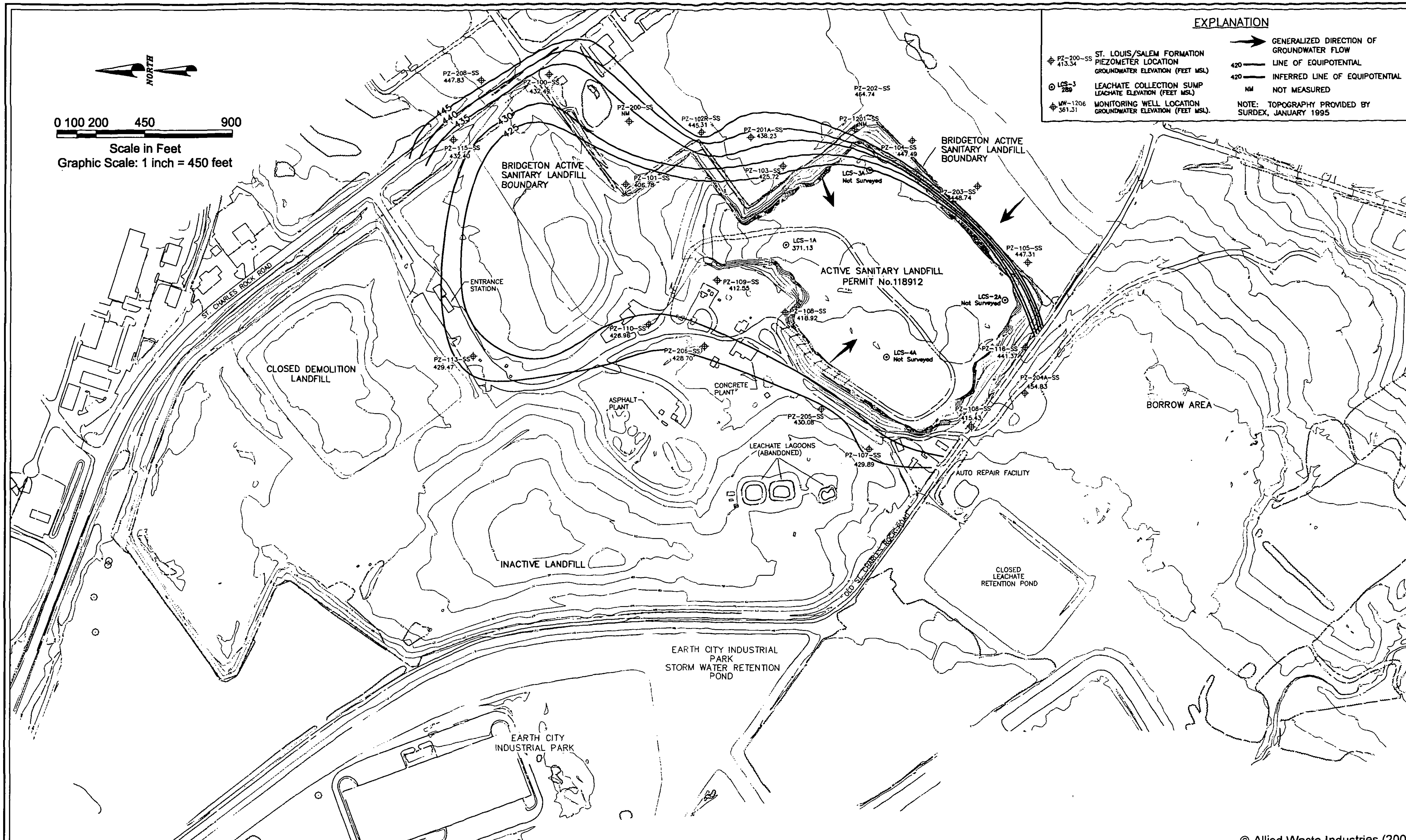

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Figure 3-36
St. Louis/Upper Salem Hydrologic Unit
May 10, 2004
Potentiometric Surface Map

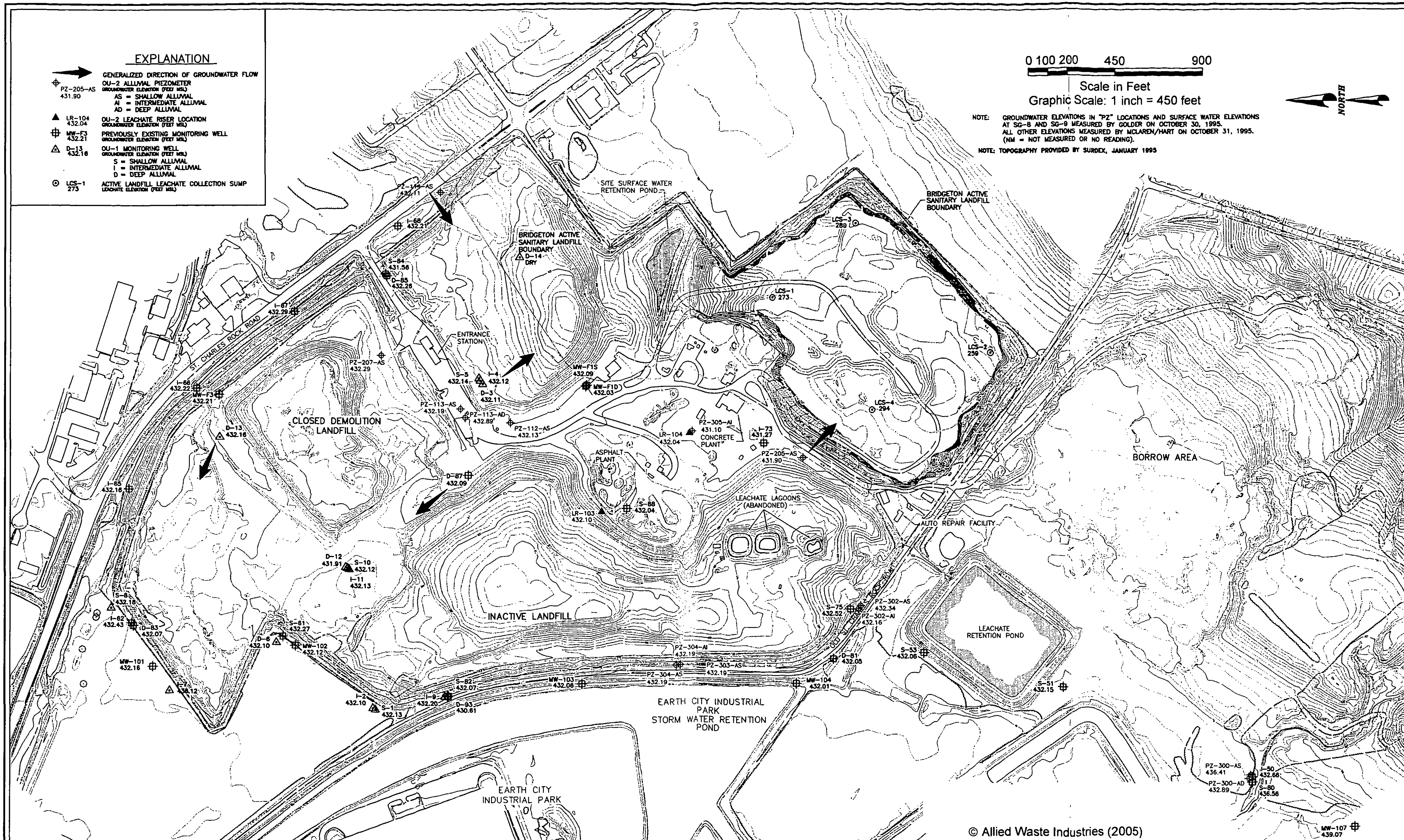

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Figure 3-37
Unconsolidated Material
October 28, 1995
Water Table Map

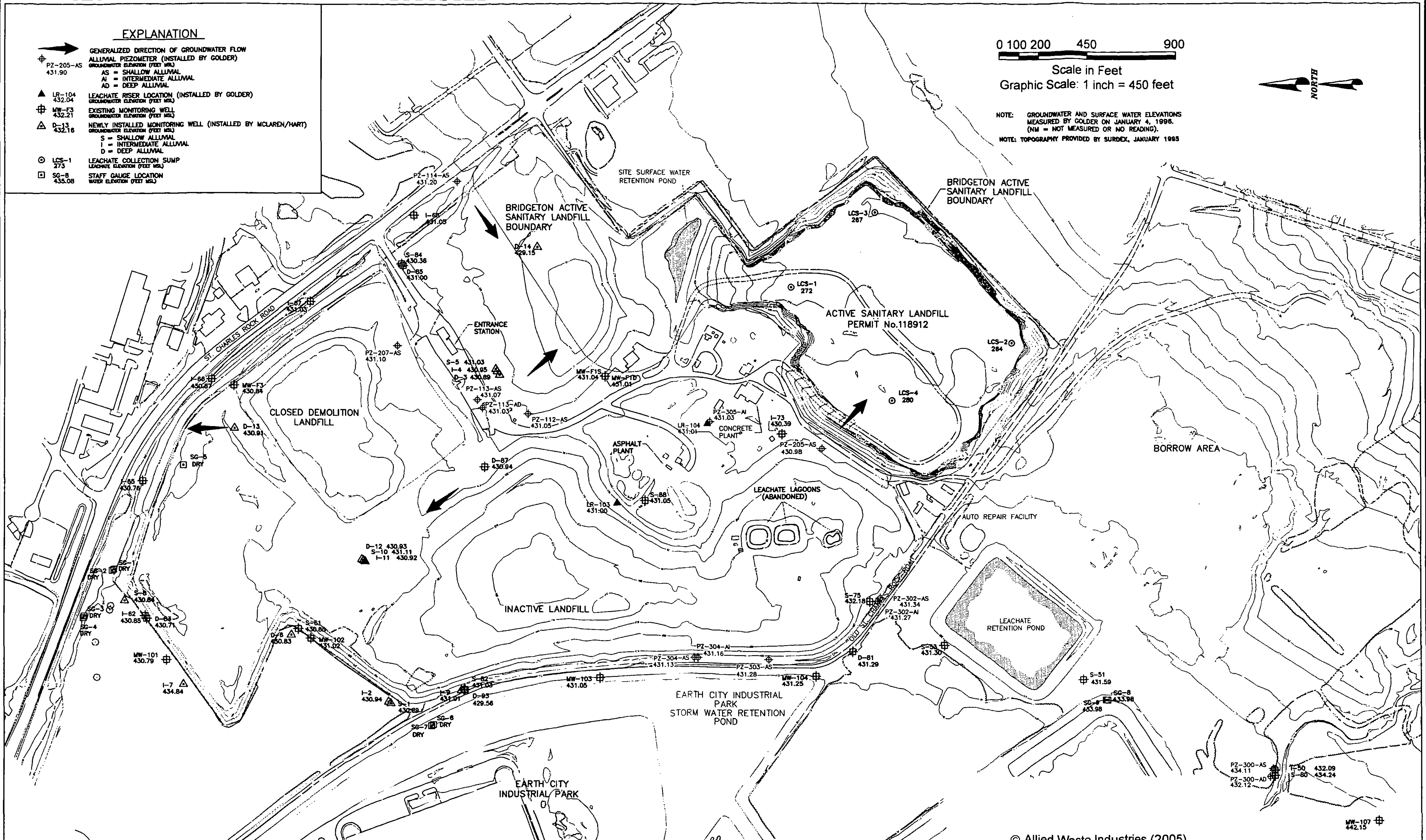

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Figure 3-38
Unconsolidated Material
January 4, 1996
Water Table Map

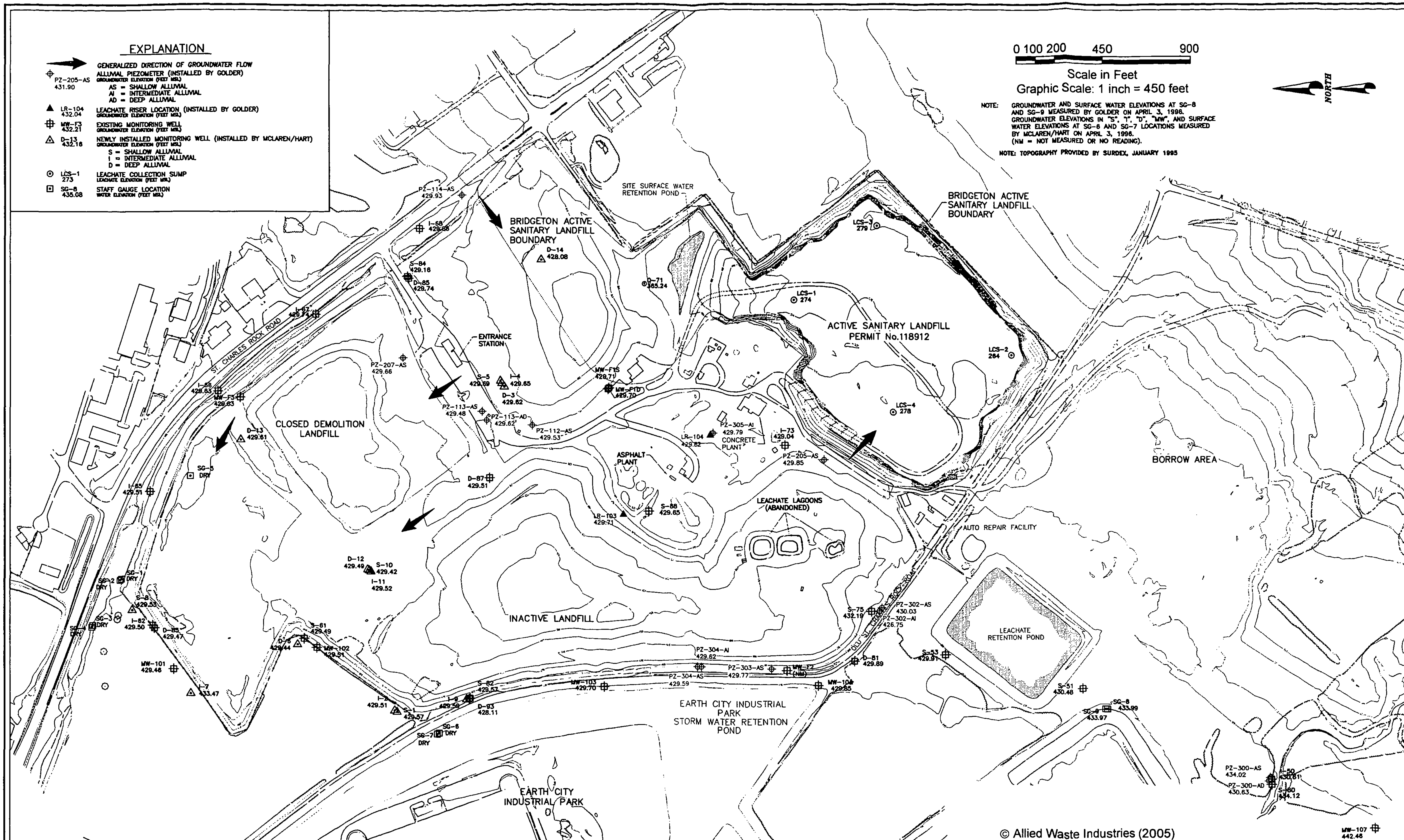

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Figure 3-39
Unconsolidated Material
April 3, 1996
Water Table Map

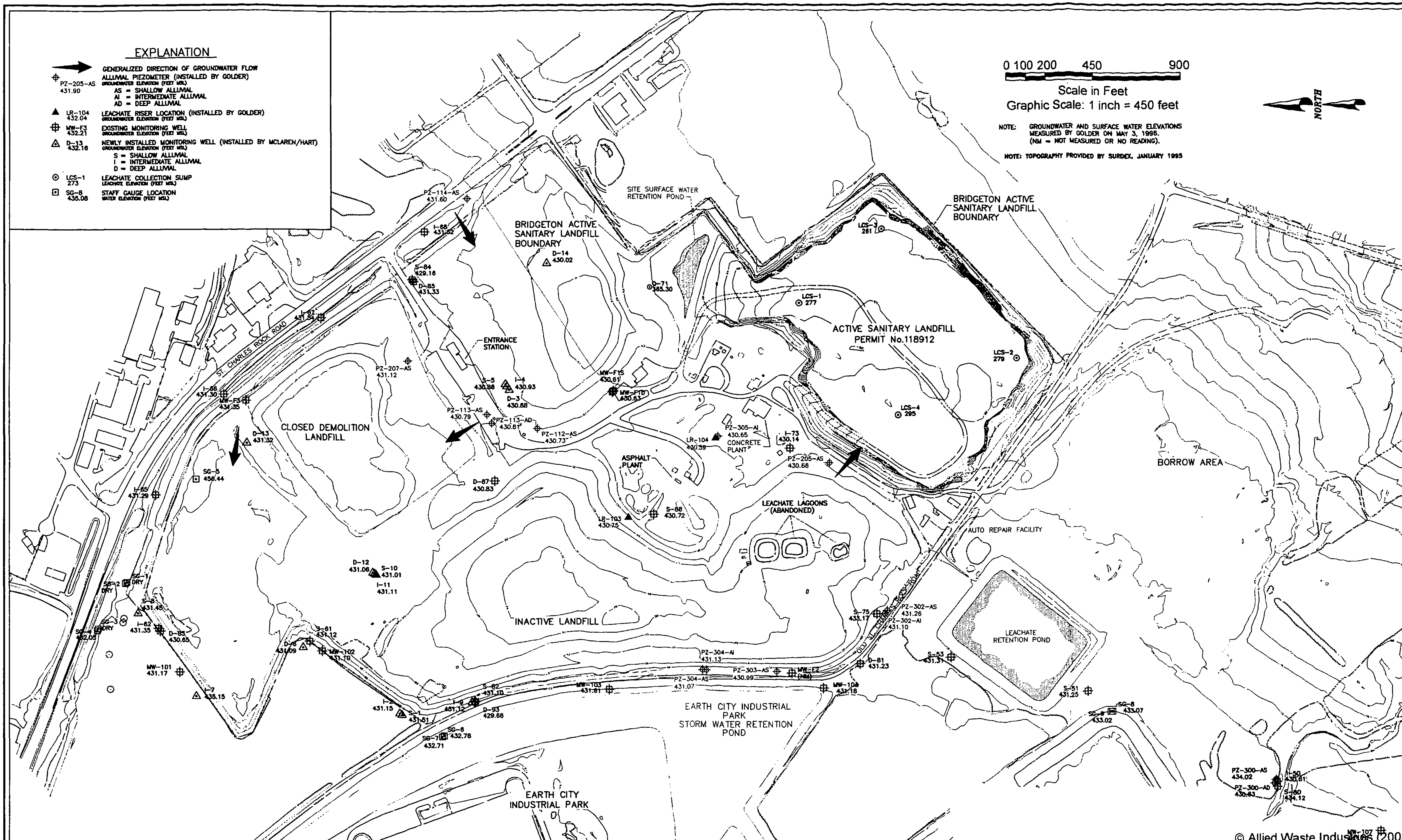

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Figure 3-40
Unconsolidated Material
May 3, 1996
Water Table Map

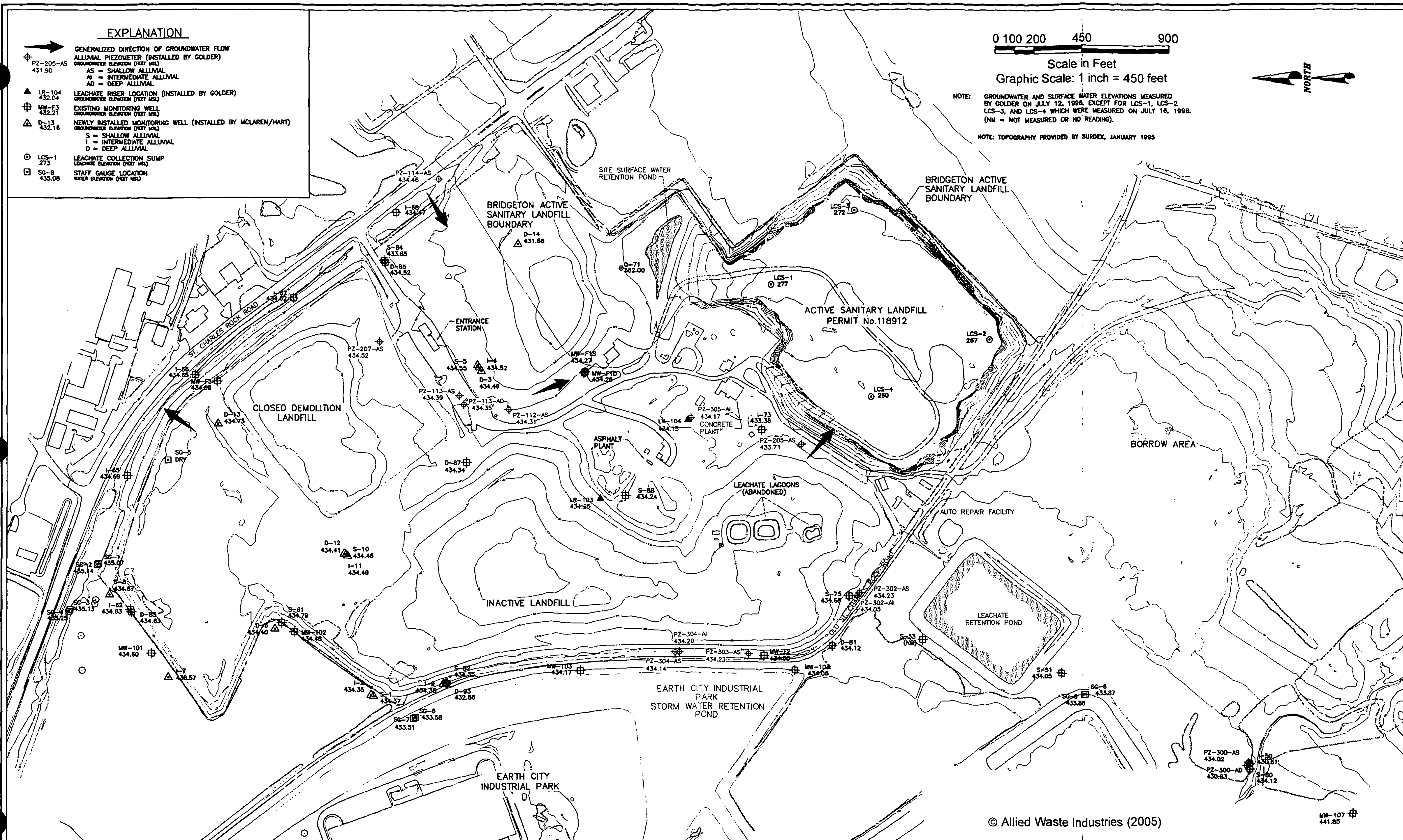

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Figure 3-41
Unconsolidated Material
July 12, 1996
Water Table Map

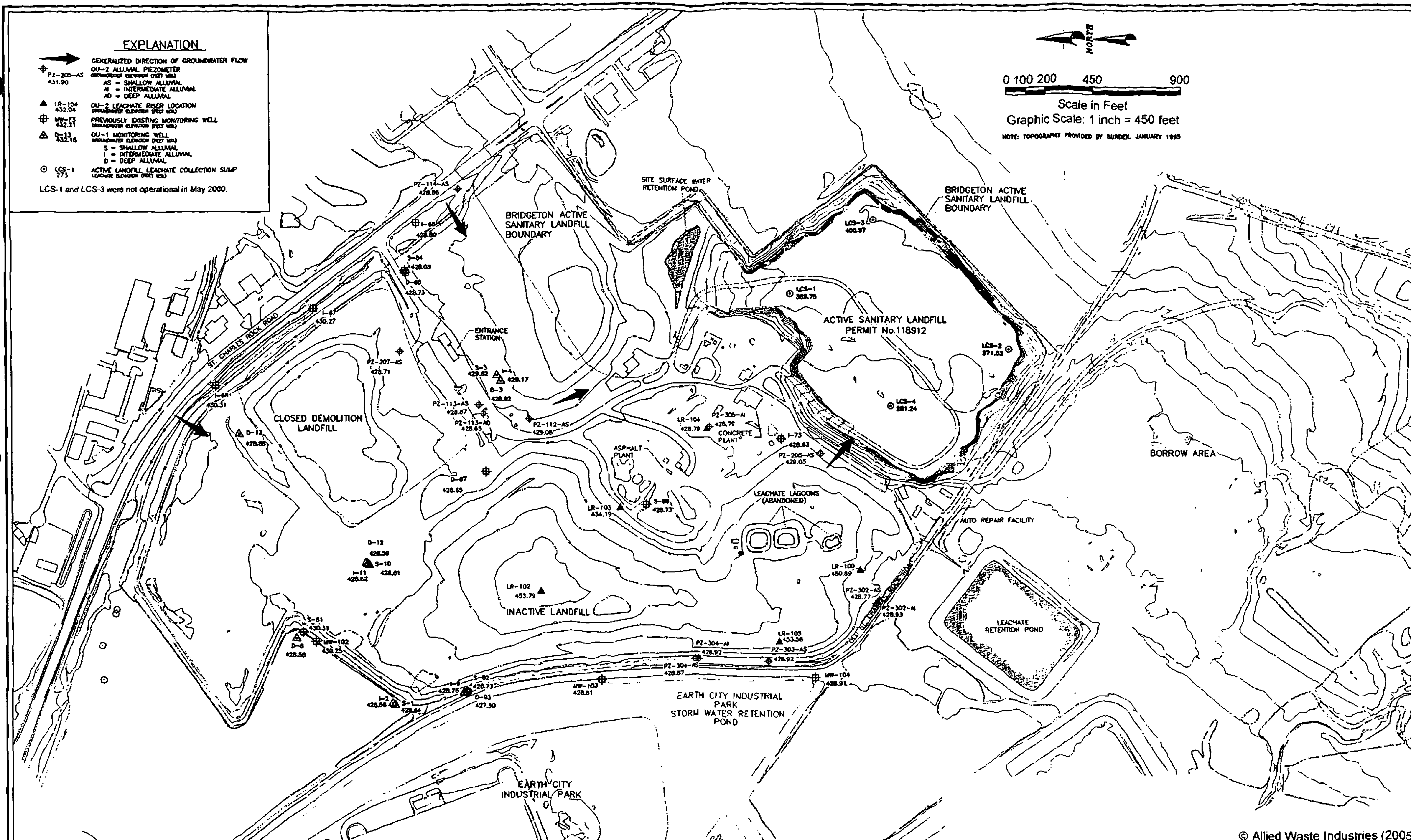

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Figure 3-42
Unconsolidated Material
May 22, 2000
Water Table Map

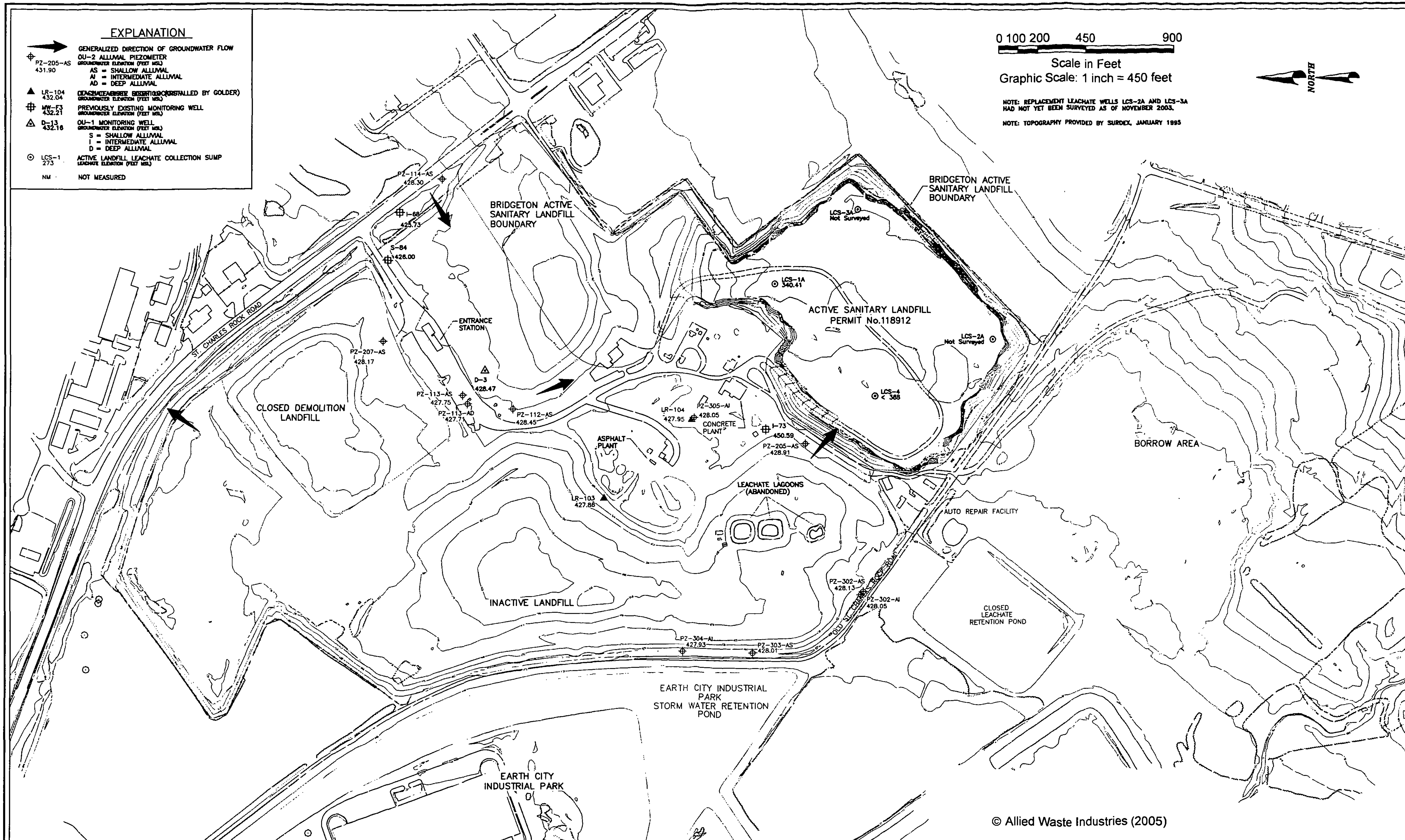

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Figure 3-43
Unconsolidated Material Unit
November 19, 2003
Water Table Map

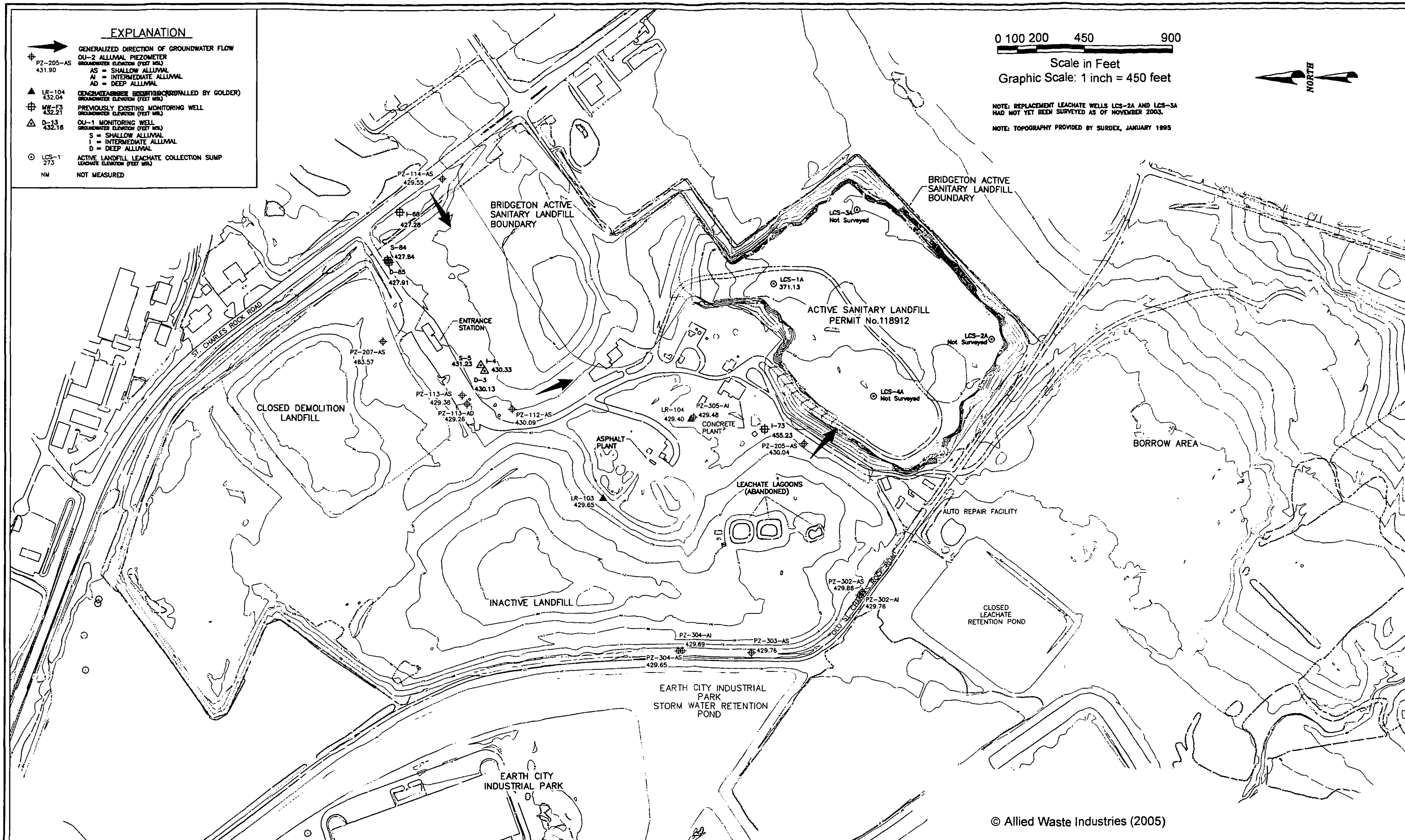

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Figure 3-44
Unconsolidated Material Unit
May 10, 2004
Water Table Map

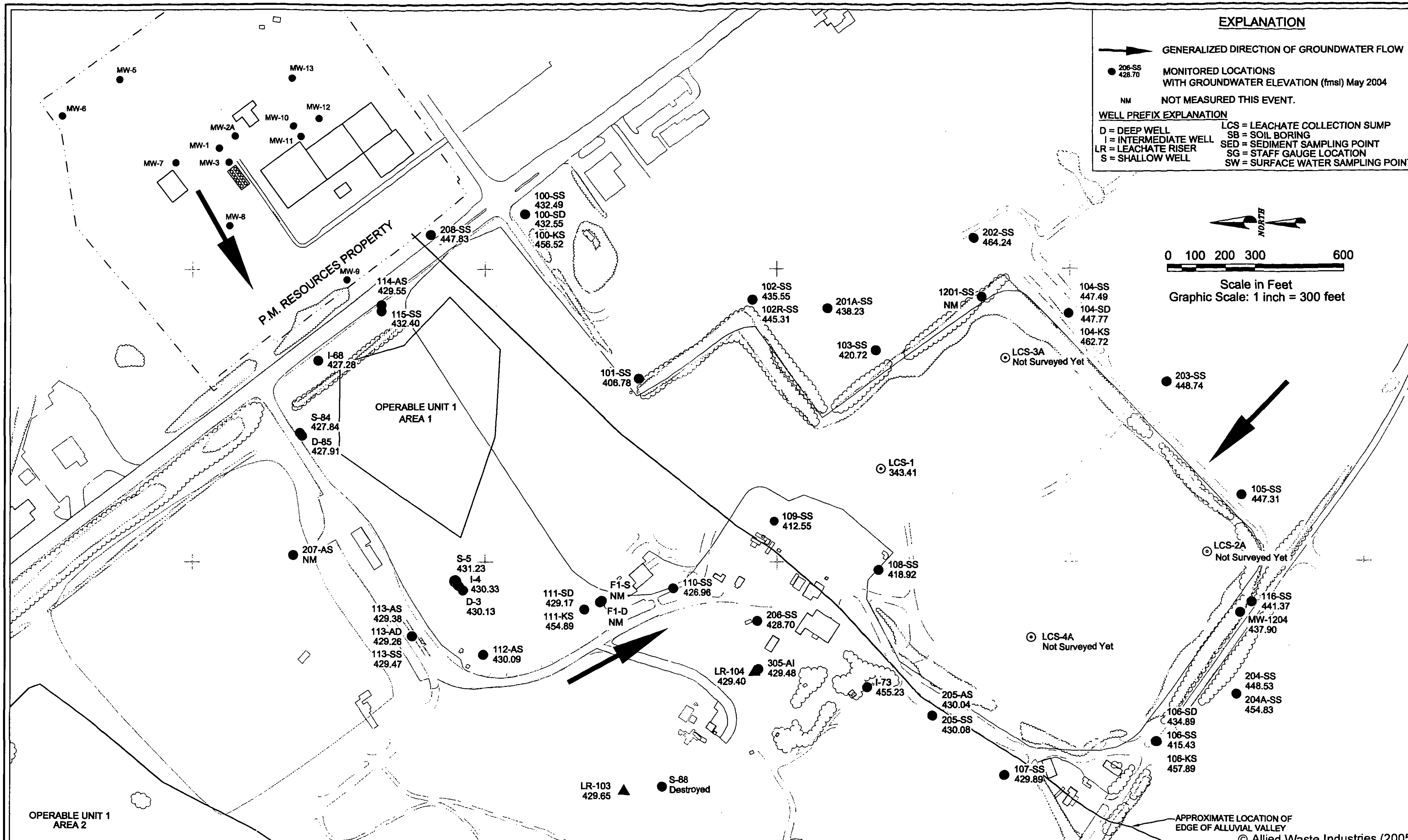

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Figure 4-2
P.M Resources
Property Location

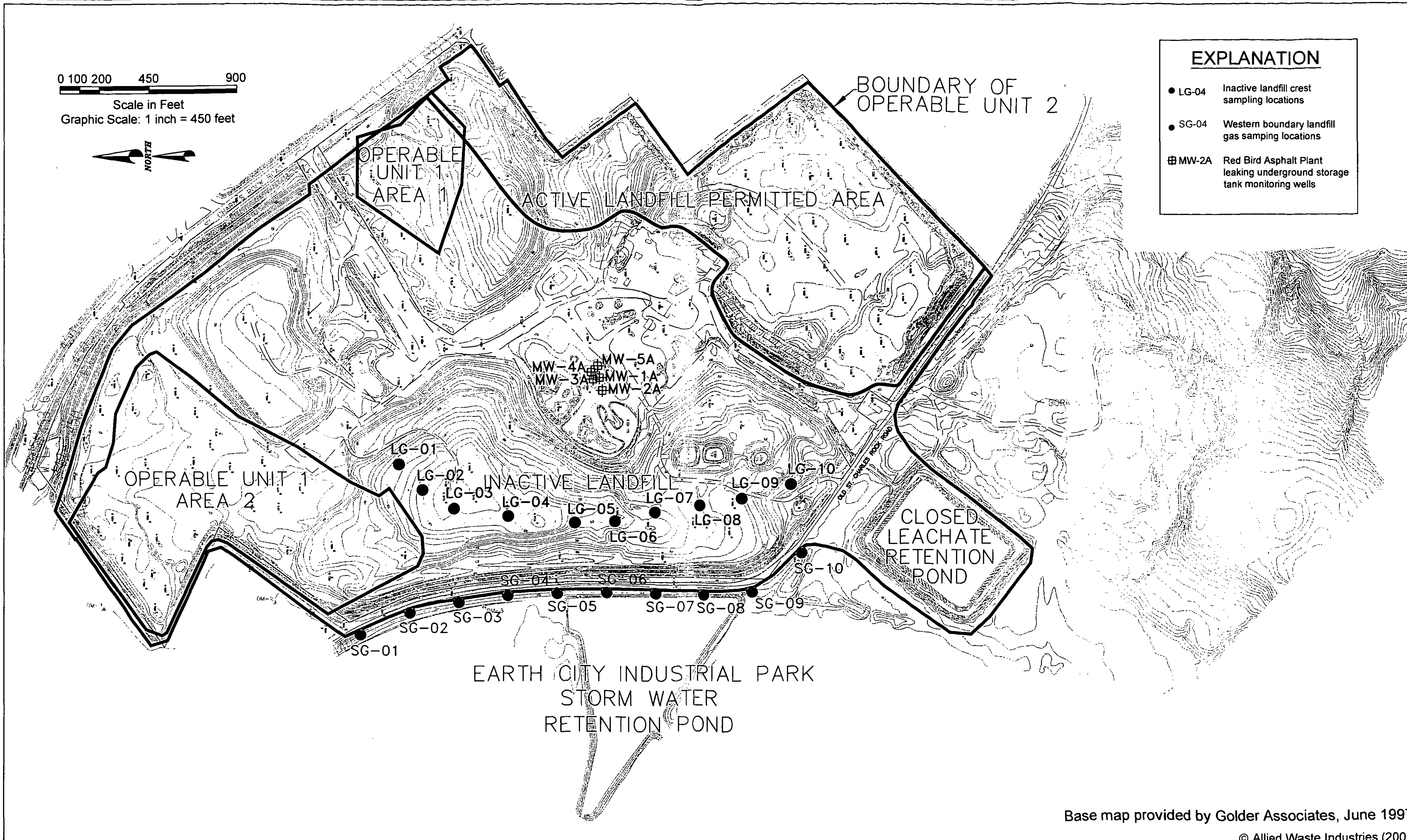

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Figure 4-3
Landfill Gas Sampling Locations

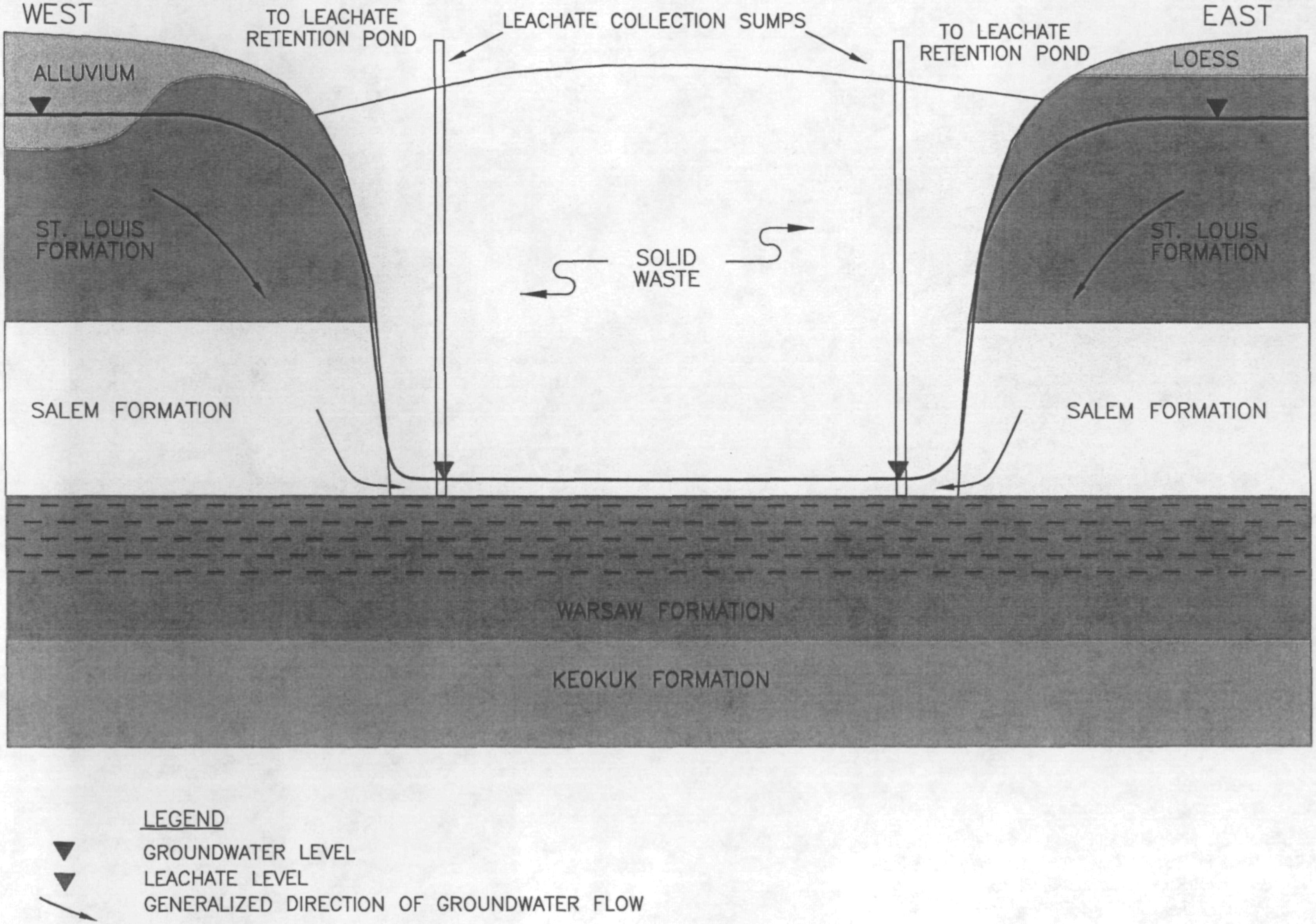

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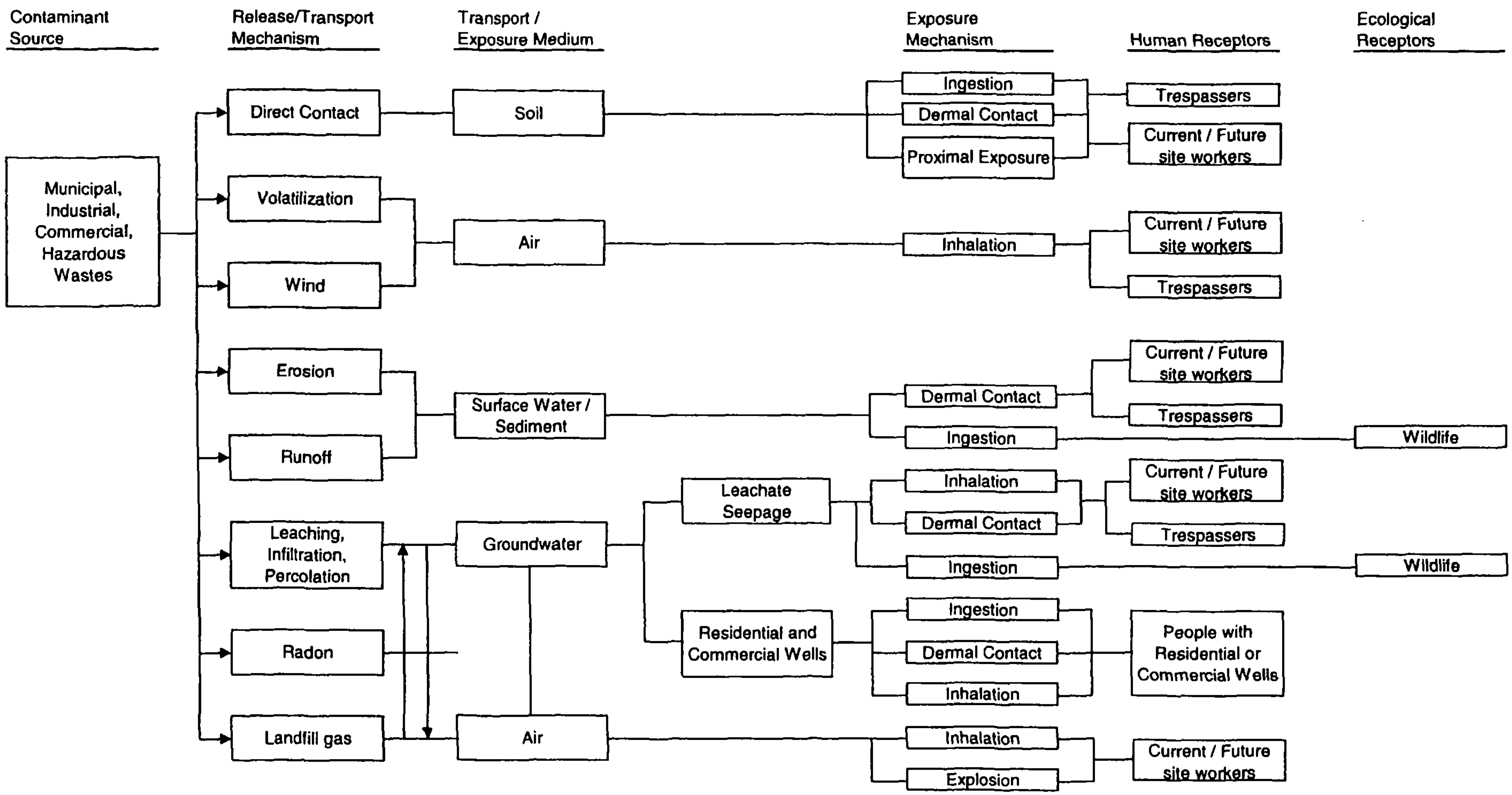
Figure 4-1
Conceptual Hydrogeologic Model



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West Lake Landfill OU-2
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Figure 6-1
Site Conceptual Model

Appendix A

Private Well Information for West Lake OU-2 Well Search (Information Provided by MDNR MEGA File)

LOG_ID	002118	003039	004478	006642	006794	007206	010022	011506	015897	019849	020676	021799	024505	024553	027190
WELL_TYPE	Noncommunity Public Well	Private Well	Private Well	Private Well	Private Well	Private Well	Industrial High Capacity Well	Private Well	Private Well	Private Well	Private Well	Private Well	WATER TEST WELL (HOLE)	WATER TEST WELL (HOLE)	
COUNTY	ST LOUIS	ST LOUIS	ST LOUIS	ST LOUIS	ST LOUIS	ST LOUIS	ST LOUIS	ST LOUIS	ST LOUIS	ST LOUIS	ST LOUIS	ST LOUIS	ST. LOUIS	ST. LOUIS	ST LOUIS
[illegible]	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189
[illegible]	C	C	NW	C	SW	NW	SW	NW		C	SE	SW	NE	SE	NW
Q[illegible]	NW	NW	SE	NE	NE	SE	SE	SW		NE	NE	NW	NE	SE	NW
QTR1	SW	SW	SW	SE	NE	SW	SW	SW		SW	NW	SE	NE	SE	NW
SECTION	02	02	36	04	34	01	34	03	34	36	35	03	34	28	33
TNSP		46	47	46	47	46	47	46	47	47	47	46	47	47	47
RNG	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05
RNGDIR	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
UTM_X	723289.0	723323.0	725297.0	721476.0	722768.0	725350.0	722014.0	721683.0	722318.0	725461.0	723884.0	722482.0	723011.0	721466.0	719958.0
UTM_Y	4292776.0	4292734.0	4294020.0	4292546.0	4295039.0	4292525.0	4293904.0	4292393.0	4294626.0	4294432.0	4295118.0	4292657.0	4295308.0	4295383.0	4295271.0
QUADMAP	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES	ST CHARLES
SCALE	24k	24k	24k	24k	24k	24k	24k	24k	24k	24k	24k	24k	24k	24k	24k
LOCATOR	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated	Interpolated
TYPELOG1	D	D	S	S	S	S	S	S	S	S	S	S	S	S	S
TYPELOG2															
TYPELOG3															
OWNER	WEST LAKE PARK & AMUSE #2	WEST LAKE PARK #1	TAYLOR (MRS.)	McGEE, CARL R.	LUECK, FRANK (MRS.)	CABIBBO	WEST LAKE QUARRY & MAT CO	HOLTSNEIDER, W.G.	HAMMEL, JESSE (HAMMEl?)	WILSON, SAM R.	REVELLE, IKE	MALONEY, JOHN	US GEOLOGICAL SURVEY	US GEOLOGICAL SURVEY	LINCLAY - EARTHCITY
DRILLER	LUTH, FRED M.	LUTH, FRED M.	CLARK BROS.	KOEBEL AND KOEBEL	FORTHMAN (FOR HOPPE)	CLARK BROS	CLARK BROS	PITTMAN BROS	ST CHALRES DRLG CO	ST CHALRES DRLG CO	ST CHALRES DRLG CO	ST CHARLES DRLG CO	USGS	USGS	LUHR BROS
DRLDATE	192607	192403	1937	194012	194012	1941	194804	195101	195705				196611	196611	
LOGGER		MCCRACKEN	GROHSKOPF	GROHSKOPF	GROHSKOPF	GOTT	MCCRACKEN	S. MARINKOVIC		ROBERTSON	ROBERTSON	J. WELLS	WELLS	WELLS	WELLS
LOGDATE						194110	194804	195101		196108	196207		196704	196704	197210
ELEV	484.0	484.0	576.0	490.0	512.0	587.0	458	506.0	-9999.0	541.0	479.0	554.0	439.0	-9999.0	430.0
PRODYLD		85		15		1.6		8	0	5	30	60			
[illegible]IBED	70.0	81.0	170.0	50.0	30.0	200.0	100.0	70.0	25.0	130.0	55.0	120.0	0.0	0.0	0.0
S[illegible]A		15		65	21				85	100					
SWLB															
WATER_AT		560'			85'				145'						
TOTDEPTH	430.0	915.0	275.0	202.0	197.0	400.0	325.0	210.0	400.0	325.0	225.0	350.0	26.0	116.0	95.0
FORM_TOP	MISSISSIPPIAN SYSTEM	ST LOUIS LIMESTONE	STE GENEVIEVE LIMESTONE	ST LOUIS LIMESTONE	STE GENEVIEVE LIMESTONE	STE GENEVIEVE LIMESTONE	ST LOUIS LIMESTONE	STE GENEVIEVE LIMESTONE	STE GENEVIEVE LIMESTONE	STE GENEVIEVE LIMESTONE	STE GENEVIEVE LIMESTONE	ST LOUIS LIMESTONE	HOLOCENE ALLUVIUM	HOLOCENE ALLUVIUM	HOLOCENE ALLUVIUM
FORM_BOT	KIMMSWICK LIMESTONE	KIMMSWICK LIMESTONE	ST LOUIS LIMESTONE	SALEM FORMATION	ST LOUIS LIMESTONE	SALEM FORMATION	WARSAW FORMATION	ST LOUIS LIMESTONE	KEOKUK-BURLINGTON LS, UNDIFF	SALEM FORMATION	ST LOUIS LIMESTONE	SALEM FORMATION	HOLOCENE ALLUVIUM	HOLOCENE ALLUVIUM	HOLOCENE ALLUVIUM
C_PLUGIND				N	N			N	N	N	N	N			
C_REMARKS															
CASING_L	0.0	0.0	0.0	62.0	30.0	200.0	0.0	76.0	29.0	125.0	67.0	118.0	0.0	0.0	0.0
REMARKS	ST CHARLES & NATURAL BRIDGE RDS. - NO UNITS IDENTIFIED	ST CHARLES & NATURAL BRIDGE RDS.	2 MI NW OF PATTONVILLE BETWEEN GIST RD & WABASH RR TRACKS	3408 LUCAS & HUNT RD, 0.5 MI SW OF ST CHARLES ROCK RD	VERY LITTLE, ON TOUSSIG RD ABT 0.25 MI N OF ST CHARLES ROCK RD	1 MI W OF LINDBURG ON S SD NATURAL BRIDGE RD			CAN'T LOCATE	4740 GARRETT RD, HAZELWOOD	13039 GIST RD., BRIDGETON		MO AUBUCHON ??	RIVER PROFILE STUDY	RELIEF WELL #1